PUBLIC LIBRARY

Established by BENJAMIN SILLIMAN in 1818.

THE AMERICAN JOURNAL OF SCIENCE.

EDITOR: EDWARD S. DANA.

ASSOCIATE EDITORS

PROFESSORS GEO. L. GOODALE, JOHN TROWBRIDGE, W. G. FARLOW AND WM. M. DAVIS, OF CAMBRIDGE,

PROFESSORS A. E. VERRILL, HENRY S. WILLIAMS AND L. V. PIRSSON, OF NEW HAVEN,

PROFESSOR GEORGE F. BARKER, OF PHILADELPHIA,
PROFESSOR JOSEPH S. AMES, OF BALTIMORE,
MR. J. S. DILLER, OF WASHINGTON.

FOURTH SERIES.

VOL. XV—[WHOLE NUMBER, CLXV.]

No. 86.—FEBRUARY, 1903.

WITH PLATE I.

NEW HAVEN, CONNECTICUT.

1903.

THE TUTTLE, MOREHOUSE & TAYLOR CO., PRINTERS, 125 TEMPLE STREET.

Published monthly. Six dollars per year, in advance. $6.40 to countries in the Postal Union. Remittances should be made either by money orders, registered letters, or bank checks (preferably on New York banks).

GUANAJUATO

Several recent shipments direct from the "Andreasberg of America" afford a large choice of the more recent finds of this famous district. Prices average lower than formerly, generally 50c. to $3.00 or $4.00 for the best cabinet specimens. Small study specimens at 15c. to 40c.

Hematite in hexagonal prisms. New and rare. Small but marvelously sharp and brilliant, coating a volcanic rock suggesting the Vesuvian examples, but of different crystalline habit.

Rose Apophyllite in handsome groups. Beautiful white and colorless crystallizations. Also detached crystals.

Hyalite. Clear masses of pearly lustre in twisted and botryoidal forms. Attractive and typical.

Fire Opal in large pieces.

Octahedral Fluor showing interesting modifications.

Quartz Crystals containing moving bubbles.

Amethyst in groups of unrivaled richness and depth of color.

Stilbite. Delicate cream-colored groups. Crystals symmetrical and well defined.

STUDY SPECIMENS

For 26 years we have supplied mining schools, universities, colleges and secondary schools throughout the world with mineralogical material. During that period the quality of our elementary and advanced collections has steadily improved, so that to-day the highest grade of study specimens are offered at unprecedentedly low prices. An inspection of our Laboratory List of minerals for analysis will show that European minerals are sold not simply below American prices, but often at lower rates than prevail in Europe. The wide connections of our European house alone permit this economy to the consumer, our prices being the same on both sides of the Atlantic.

Illustrated Collection Catalog Free.

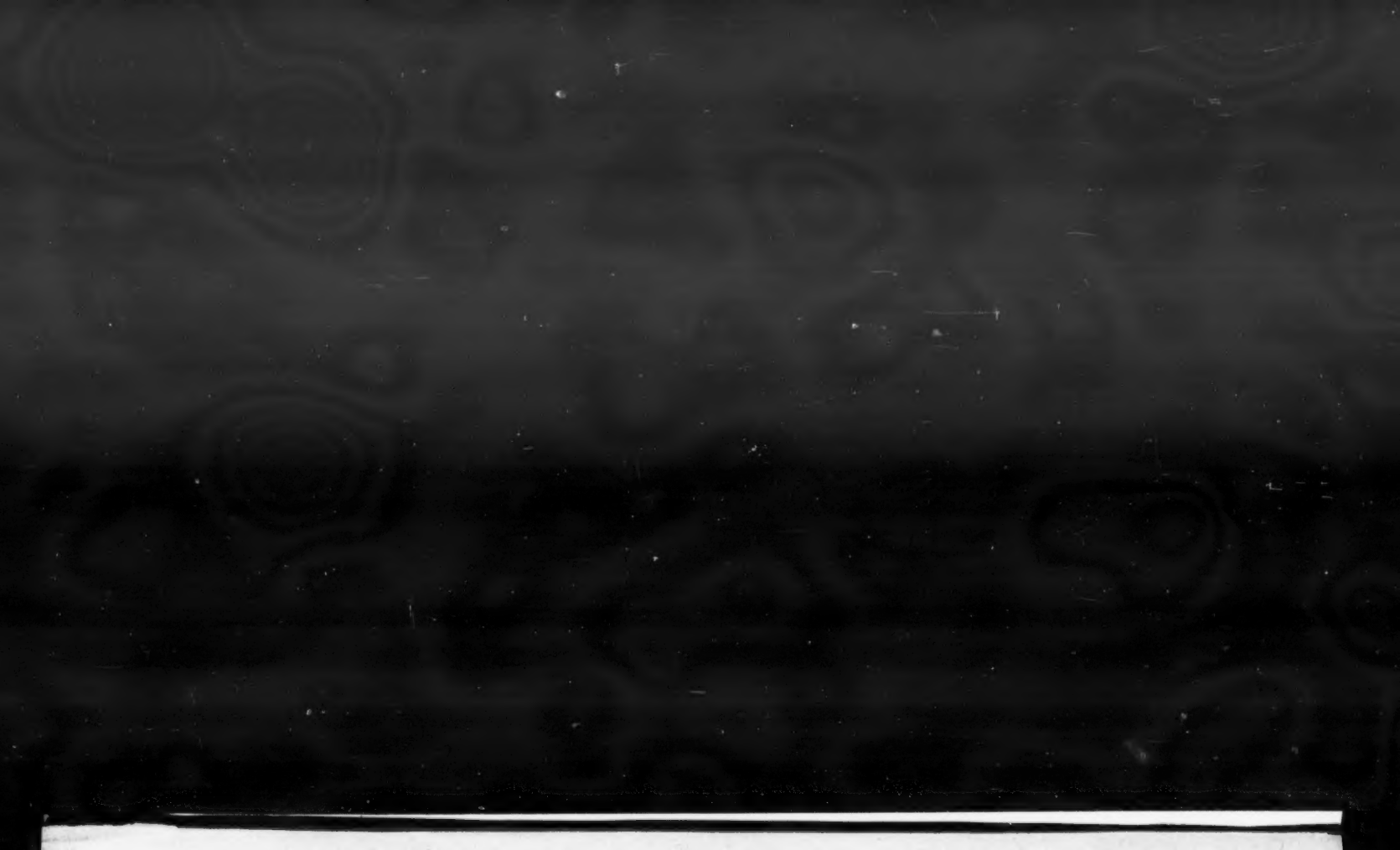
The Largest and Most Complete Stock of Scientific and Educational Minerals in the World. Highest Awards at Nine Expositions.

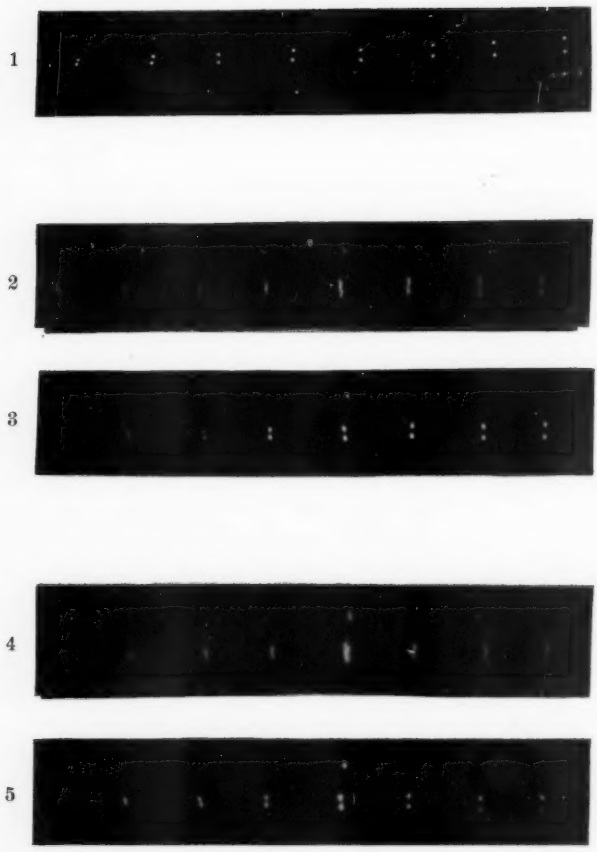
FOOTE MINERAL CO.,

FORMERLY DR. A. E. FOOTE,

PHILADELPHIA,
1317 Arch Street.

PARIS,
24 Rue du Champ de Mars.





Experiments on artificial good seeing. Smithsonian Astrophysical Observatory.

No. 1. The object, a series of artificial double stars.
2. { Image of No. 1, without stirring } exposure, 3 minutes.
3. { Image of No. 1, with stirring }
4. { Image of No. 1, without stirring } exposure, 4 minutes.
5. { Image of No. 1, with stirring }

THE

AMERICAN JOURNAL OF SCIENCE

[FOURTH SERIES.]

ART. VI.—"*Good Seeing*";* by S. P. LANGLEY. (With Plate I.)

EVERY one who has used a telescope knows that our atmosphere is forever in pulsating motion, and troubling our vision of the heavenly bodies, during the most cloudless day or night, so that observatories are put even on high mountains, to get rid of the disturbances in this atmosphere, which tend to make the image of every object tremulous and indefinite, and to prevent what the astronomer terms "good seeing."

I desire to speak to the Academy about a device which I have recently essayed for preventing this universally known and dreaded "boiling" of the telescopic image, a difficulty which has existed always and everywhere since telescopes have been in use, and which has seemed so insurmountable that I believe it has hardly ever been thought of as subject to correction.

Hitherto it has been the endeavor of astronomers, so far as I know, to secure a more tranquil image by keeping the air in the telescope tube, through which the rays pass, as quiet as possible, and for this purpose the walls of the tube have been made non-conducting, and extreme pains have been taken not to set up currents in the tube. With these precautions the "seeing" is perhaps a little better (but very little) than if none were used at all, the main difficulty having been always found insurmountable.

I have been led for some years to consider the conditions under which this "boiling" presents itself. It is not necessarily due to a high temperature of the external air, for the most perfect definition I have ever seen of any terrestrial object was obtained by me long since in the Harvard College Observatory at Cambridge, with its great equatorial telescope, when, on the hottest day that I ever knew in a New England summer, I

* A paper presented to the National Academy of Sciences, November 12, 1902.

directed it with a high power on the distant "south mark," which I expected to find almost indistinguishable from the "boiling." I remember my extreme surprise when, under a magnifying power of 300, I found the image as still as the lines of an engraving. This was an extraordinary exception to ordinary experience, and led me to take an interest in the subject. I have since pursued an inquiry to which this circumstance first directed my attention, and I have done so at all altitudes, at one time residing on Aetna for this purpose, noting that even on high mountains telescopic vision was so far from being always clear that it was sometimes even much worse than at sea level.

I have since come to the important conclusion that while the ordinary "boiling" is due to all the air between us and the sun or star through which the rays pass, the greater portion of it is due to the air immediately near us, probably within a few hundred yards or even feet from the telescope, and this has led me to ask whether it was not possible that some way to act upon this air could be found. Its non-uniformity leads to deformations of the image too complex to analyze here, which are caused not only by lateral vibrations of the cone of rays, but by its elongation and contraction.

For this purpose I have, within the last few months, been making experiments at the Smithsonian Astrophysical Observatory; first with a horizontal tube having three successive walls with air spaces between, which was intended to give the maximum security which freedom from changes of temperature could afford. This observatory being principally concerned with rays best studied in an image formed by reflection, has no large dioptric telescope, on which account these experiments have been made with a reflector. I have no reason to suppose, however, that they will not be equally successful with a dioptric telescope.

A large part of the "boiling" of the image is due to air without the tube, but a not unimportant part to the air within it; and in the preliminary experiments the air, kept still in the tube by treating it with the ordinary precautions, was found to have little effect on the ordinary "boiling" of the image, which so seriously prejudices the definition. An image-forming mirror, fed by a coelostat, was placed at the end of this triple-walled tube, which was itself sheltered by a canvas tent, and contained the stillest air of the most uniform temperature which could be obtained. The "boiling" was but little diminished merely by enclosing the beam by this tube, which was only what had been anticipated from the ordinary experience of all astronomers.

The device which I had determined to try was one of a paradoxical character, for it proposed to substitute for this still air which gave the usual troubled image, agitated air which it

was hoped would give a still image.* For the purpose of this new experiment, the horizontal telescope using a reflector of 40 feet focus, fed by a coelostat through the above tube, was connected with a fan run by an electric motor, which was arranged to draw out the air from the inner tube, at the same time that it forced air in at different points in its length, so as to thus violently disturb and churn the air along all the path of the beam from the coelostat to the solar image.

This first experiment gratifyingly reduced the "boiling" and produced an incontestibly stiller image than when still air was used. As a further test, a series of artificial double stars was now provided, and the concave mirror, acting both as collimator and objective, brought the images to focus, where they were examined with an eyepiece. With the stillest air obtainable, the images were not sharp and only the coarsest doubles were resolvable. Then the blower was started and the definition immediately became sharp. Violently stirring the air in the tube, then, eliminates all or nearly all the "boiling" of the stellar image which arises within the tube itself when using ordinary still air. This experiment concerned the air within the horizontal tube only.

I have next taken up the solar image formed by the mirror in the above tube. This is clearly improved by the stirring. I have also wished to try a tube something like a prolonged dew cap, but which is arranged to be inclined toward the sun. The air in both can be stirred together, but experiment has not yet gone far enough to demonstrate whether it has, as is hoped, any superiority commensurate with the special mechanical difficulties involved.

I am not prepared to give quantitative estimates, which I hope to furnish later; but all observers to whom I have shown these early results on the sun have agreed, that if the "boiling" was not wholly cured, what remained was but a small fraction of that obtained with still air. I have not completed these experiments, which I am still pursuing at the observatory, but they seem to me to give promise of an improvement of universal interest to observers, which justified the making of this early announcement. I had hoped to have shown the Academy some photographs of the sun taken, first, in the ordinary way, and again, with the churned air, but the condition both of the sun and of the sky, of late, has prevented my obtaining them. I can, to my regret, only give here a photograph of the images of the artificial double stars as seen through ordinary conditions, as distinguished from those here mentioned, of artificial "good seeing."

Astrophysical Observatory, Washington, November 12, 1902.

* I may mention here that my lamented friend, Henry C. Draper, once showed me that agitating the contents of a bisulphide of carbon prism improved its definition.

ART. VII. — *Native Arsenic from Montreal;* by NEVIL NORTON EVANS.

AT the end of last July, Mr. Edward Ardley, Assistant at the Peter Redpath Museum, McGill University, Montreal, brought to the writer for identification a mineral found in a vein cutting the nepheline syenite of the Corporation (Forsyth's) Quarry near Montreal. The specimen proved to be native arsenic.* As far as the writer has been able to ascertain, this mineral has been found at but two other localities in Canada: on the west bank of the Fraser River, a short distance above Lillooet, B. C.;† and at Edwards Island, Thunder Bay District, Lake Superior, nine miles east of Silver Islet.‡ The Montreal occurrence is therefore quite remote from those previously recorded, and it was thought that a careful examination and description would prove of interest.

The main portion of Mount Royal is formed of essexite, but a later intrusion of nepheline syenite occurs on the northern slope between the essexite on the one side and the Chazy limestone of the surrounding plain on the other, the limestone having been markedly altered thereby and rendered highly crystalline. The nepheline syenite is grey in color and rather fine in grain, and belongs to the foyaite type of this rock; it is composed of orthoclase, oligoclase, nepheline, and a hornblende very deep green in color, allied to if not identical with hastingsite, together with subordinate amounts of pyroxene, garnet and nosean. The vein containing the arsenic was found traversing the syenite nearly vertically, small horizontal stringers running off here and there, chiefly on one side, and a few veinlets branching off and then running parallel to the main vein. The vein was lenticular in form, having a width of one and three-quarter inches in the widest part, and narrowing down to about one-eighth inch above and below. The thicker portion, which measured about ten feet vertically and three feet horizontally, contained the arsenic, and probably forty pounds of the mineral were removed. There is at present no indication of another widening of the vein lower down, with a further content of arsenic.

Associated with the arsenic were found calcite in considerable quantity, with realgar and pyrites in exceedingly small quantities; in some places, where they occurred in druses, the crystals of calcite (scalenohedra) were sifted over with very

* See this Journal, xiv, 397.

† Ann. Report Geol. Survey, Canada, 1896, part T, p. 9; and 1887–88, part R, pp. 106, 161.

‡ Ferrier: Canadian Record of Science, iv (1890–91), p. 472.

minute black reniform particles, which on account of their extremely small size could not be accurately determined, but which were some silicate of iron soluble in hydrochloric acid and yielding gelatinous silica on evaporation. There were a few little pockets filled with a soft black substance, moist, and hardening on drying in the air. This seemed to be closely allied in composition to the little particles mentioned above, and on its free surfaces it exhibited a similar minute glossy reniform structure.

The arsenic itself is the variety known as "scherbenkobalt"; it is in large masses, often several pounds in weight, formed of concentric layers. It appears as though deposition, probably due to some fumarole action, had started at certain points on the wall of the vein and layer after layer of the arsenic had been added, producing a sort of onion-like lump of the material. In time these masses grew into one another, giving a reniform structure to the whole. Here and there on the surfaces of the masses there are traces of crystalline structure, with angles apparently of 90°; but no faces were found well enough developed to allow of any measurements being taken. The mineral exhibits the usual characteristics of native arsenic; the mean of two analyses gave its composition as:

Arsenic	98·14%
Antimony	1·65
Sulphur	0·16
Insoluble	0·15
	100·10

No silver, bismuth or other element was found, although carefully looked for. Two specimens gave for specific gravity 5·73 and 5·75 at 18°. The hardness is between 3 and 4.

The deposit seems to be notable on account of the purity of the arsenic, its large quantity, and the absence of associated sulphides.

Macdonald Chemical Laboratory,
McGill University, Montreal.

Art. VIII. — *Electromotive Force in Plants;* by Amon B. Plowman.

Every disturbance of the atomic relations within any material body is, in all probability, attended by a more or less pronounced electrical disturbance in the ether surrounding the atom. Whether or not this condition of electrical stress can be detected depends upon the amplitude of the atomic displacement, the nature of the body, and the sensitiveness of the instruments used. Thus when copper and zinc plates are placed in a dilute solution of sulphuric acid there is an interchange of atoms between metal and acid, and the rate of interchange is so much greater in the case of zinc that the electrical equilibrium of the system is at once destroyed, and this disturbance is easily shown by means of suitable apparatus. Here, as in all cases, the galvanic current is the manifestation of a difference of atomic activity in two parts of a closed circuit, and this in turn is due to a difference in "solution tension" or "chemical affinity" of the substances employed. The diffusion of liquids is attended by similar electrical phenomenon. For example, when two solutions of different concentration of the same substance are brought in contact, the greater solution tension of the more concentrated solution forces its ions into the weaker solution more rapidly than the ions of the latter move in the opposite direction, and we have what is known as a "concentration element." Since hydrogen and hydroxyl ions take the lead for rapidity of motion in solutions, we find that the more dilute solution of an acid is positively charged ($\overset{+}{\mathrm{H}}$) in the concentration element, while the more dilute solution of a base is always negatively charged ($\overline{\mathrm{OH}}$).

We may say then, in general, that wherever there are diffusion currents in non-homogeneous liquids, or—even more broadly stated—where there are differences of solution tension in the parts of a material body, there will be electrical differences of a corresponding magnitude.

In view of these facts it is not at all surprising to find that living organisms frequently show well-marked evidence of electrical disturbances within their bodies. Considering the great variety of substances which enter into the composition of an ordinary plant body, the presence of diffusion currents as an ever-essential condition, and the comparatively high resistance offered by living tissues to the passage of electrical currents, it is fair to expect a difference of electrical potential in the parts of such a body when performing its normal functions.

The first systematic study of the electrical properties of plants was made by Prof. J. Burdon Sanderson, in a series of experiments on the electromotive properties of the leaf of Dionæa.* His work was characterized by more than usual care, and while some of his conclusions do not seem to be fully justified by the results, this is in many respects the most satisfactory piece of work in biological physics up to the close of the last century. In order to avoid as far as possible any mechanical injury to the plant, Sanderson used contacts of a paste made of pure clay worked up with a dilute solution of common salt. This mixture was contained in glass tubes leading off to a contact with a saturated solution of zinc sulphate, which in turn was in contact with rods of pure zinc, thus forming so-called "non-polarizable electrodes." With such an arrangement there must be a certain amount of diffusion between the dilute NaCl solution in the clay and the saturated $ZnSO_4$ solution, and in all probability there is more or less diffusion at the leaf-contact itself. So that while this form of contact is probably the best yet devised, it certainly leaves very much to be desired in the way of freedom from possible inherent electromotive force. Where the differences of potential to be measured are of the order of 1×10^{-4} volt, or even much less, it is highly essential that all electromotive force be eliminated from the contact terminals. Sanderson's use of terms in describing electrical conditions is often somewhat vague and confusing. Thus he speaks of relative "positivity" and "negativity" of parts, but fails to state definitely in what sense these terms are used. For example, when he says that "the upper surface is positive to the lower, but that under certain conditions this may change to relative negativity," we have no means of knowing whether he is speaking of the internal circuit or the external circuit. Just as in a Daniell cell, the copper element is positive with reference to the external circuit, and the zinc is positive with reference to the internal circuit, so here such a statement as the one quoted above does not give any information regarding the direction of the current.

The more important conclusions arrived at by Sanderson were, in effect, as follows:

I. In a healthy leaf of Dionæa, in the unexcited state, there is a difference of electrical potential between the upper and under parts of the lobe; the midrib and the lobes; and also between different parts of the midrib.

II. When the leaf is excited this difference of potential between the two surfaces undergoes a sudden reversal of sign, sometimes preceded by a momentary increase of difference in

* Proc. Royal Soc., London, 1881 and 1882. Nature, x, 1874.

the same direction, and followed by a slow return to the normal state.

III. This reversal of sign occurs when the leaf is excited either mechanically or electrically, in the same or the opposite lobe.

IV. Repeated excitation of the leaf reduces the normal difference of potential, and may even reverse its sign for a considerable length of time.

V. Very slight electric shock tends to increase the normal potential difference without reversal of sign and regardless of the direction of the applied current.

VI. In addition to these conclusions, we may readily infer that Sanderson considers the transfer of impulses in the plant as of an electrical nature.

From a repetition of some parts of Sanderson's work it appears that the above conclusions are, in the main, correctly drawn. It is the purpose of this paper to offer some hints as to the explanation, from a purely physical point of view, of the phenomena on which those conclusions are based.

1. As has already been pointed out, it is to be expected that different parts of a living, functionally active plant will show differences of electrical potential. Hence the first conclusion may be accepted without further question.

2. The mechanical closure of the lobes of a Dionæa leaf consists in a sudden loss of turgor by the cells on the upper or inner side of the "hinge," and a slow increase of turgor on the lower side. The disturbance on the upper side is of a truly molar order, while that on the lower side is comparable to molecular movements. The protoplasm of the upper parts may merely cease to be active upon receiving the impulse, or it may undergo a sudden modification before becoming passive. That these changes in condition of the protoplasm, as well as the shifting relations of the cell-sap, excite differences of electrical potential, is highly probable, to say the least.

3. Since the electrical phenomena shown by the excited lobe are the result of its *response* to the stimulus, it is not to be supposed that they will be modified by the varying *source* of the stimulus.

4. Repeated excitation of E.M.F. in the leaf, followed in each case by diffusion of the charge through the tissues, must increase the number of free ions in the solution,* and thus the conductivity is increased. As a result, the slight normal difference of potential is more quickly neutralized and becomes imperceptible. Reversal of sign must apparently be attributed to "fatigue" of the protoplasm in one part of the leaf.

* See paper by A. Crum Brown on "The Ions of Electrolysis," Science, xv, 388.

5. Extremely slight electrical shock does not appreciably disturb the degree of dissociation of a solution, and so does not increase its conductivity. But many experiments show that even almost imperceptible shock stimulates protoplasmic activity to a marked degree. In the leaf this increased activity would naturally be more pronounced in the part already active than in that which is comparatively passive.

6. The question of the nature of the transfer of impulses through living protoplasm must remain properly a biological problem until the mechanism of protoplasm itself is more fully understood. That the transfer of an impulse is attended by

Fig. 1.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A																
B		1	2	2	3	3	4	4	4	4	5	6	5	5		
C		1	3	4	3	3	3	3	3	3	4	5	4	4		
D		2	1	1	2	2	2	2	2	2	3	3	3	3		
E	–	25	5	3	2	2	1	1	1	2	2	4	8	25	+	
F		2	2	2	2	2	2	2	2	2	2	3	3	3		
G		1	2	2	1	1	1	1	1	2	2	2	2	3		
H		0	1	1	2	3	4	4	4	4	4	3	3	2		
I																

Fig. 2.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
A																
B																
C	1	1											1	1	1	
D	3	3	2	1								1	1	1 2	2	
E	4 –	2 11	1 6	3	1						1	2	1 4	2 7	4 +	
F	5	3 4	1 3	2	1							1	1 1	2 2	5	
G	4	2 3	2	1									1	1 1	2	
H	2	1													1	
I																

an electrical disturbance, can hardly be questioned. That an electrical shock of slight intensity is capable of exciting the protoplasm is equally certain. Apparently the separation of impulse transference, electromotive force, and protoplasmic response is a difficult problem. If the rate of transfer could be measured accurately it would probably offer a solution. But this, independently of the time of protoplasmic response, has not been measured.

The spreading of an electric current to all parts of a leaf through which it is flowing, and the distribution of the reaction current which follows, may be shown by simple experiments to be precisely analogous to the similar phenomena in non-living bodies.

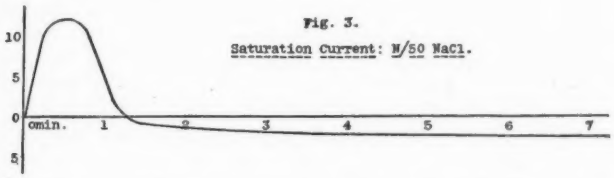


Fig. 1 represents a rectangular piece of filter paper which was saturated with N/50 NaCl, and through which a 1v. ·1 amp. current was passed between the points marked + and −. With galvanometer terminals 1^{cm} apart, the entire field was explored on the lines B, C, D, . . . H. The potential difference in each case is recorded on the line joining the points of contact, and in units of 1×10^{-3} volt. After the battery current was turned off, the field was again explored and recorded in the same units, fig. 2. Values less than unity are not recorded. At no part of the field was the potential difference imperceptible with a galvanometer sensitive to 1×10^{-6} volt. Of course the current flowed in the same direction through the galvanometer as before, since it passed in the *opposite* direction through the paper. (We are inclined to believe that Sanderson was in error on this point in some cases.) From this well-known tendency of the electric current to spread over the entire conductor, it seems quite possible that electrical stimulation of one lobe of Dionæa may spread, as an electrical disturbance, to the other lobe.

The generation of E.M.F. by diffusion and difference of concentration is shown graphically in fig. 3. In this and the following figures the unit potential is 1×10^{-3} volt. Potential differences are always represented by vertical displacement of the curve, while time units are plotted on the horizontal axis. A piece of filter paper 10^{cm} square was rolled tightly, and the platinum-wire terminals of the galvanometer were inserted in the

ends of the roll. So long as the paper was dry there was, of course, no current. Calling one end of the roll "A" and the other "B" we shall represent any current from "A" to "B" through the paper by displacement of the curve upward from the zero line. N/50 NaCl was now added slowly to the paper at "A." When the moisture reached "B" there was a rapid deflection of the mirror, which increased for about 20 sec., then fell to zero at 1 min. 20 sec., then slowly turned in the opposite direction, but not so far as it had gone in the first direction. For an explanation of this we must, no doubt, look to the different diffusion velocities of the free ions in the solution.

The next five figures represent the "reaction currents" of solutions of various salts. In each case a roll of filter paper was arranged as for determining the "saturation current," with the difference that it was uniformly saturated at once. After passing a 3v. current through the roll for one second the galvanometer circuit was closed and the reaction current was noted. Of course the reaction current was always in the direction opposite to that of the battery current, through the paper. The peculiarities of the curves may be readily and satisfactorily explained on the principles of physical chemistry, but our present attention should be directed rather to the striking similarity between these curves and those in figs. 9, 10, 11 and 12, which represent the reaction currents in various plants after forcing a 3v. current through them. The direction of the reaction is always opposed to that of the battery current. A comparison of figs. 5 and 11, 7 and 10, 8 and 9, 6 and 12, makes this similarity fully apparent. The longer action of the forced current in the plants is necessitated by their higher resistance, which means that the compounds in them yield less readily to electrolytic dissociation. The only difference worthy of note is the presence in the plants of a "normal current" of greater or less intensity. All the figures show the temporary reduction of this current by the action of the forced current.

Fig. 12 deserves special notice, since it furnished the first hint of the diurnal variation in the normal plant-current. The plant used in this experiment showed a normal upward current of ·8 between two points 20^{cm} apart on the stem. The usual battery current was passed upward through the stem for 10 min., with the reaction shown at I in the figure. At II the forced current was repeated. Its reaction is slightly more abrupt in neutralization. At III the forced current was again repeated. The reaction was still more abrupt, and also more intense, owing to the increased conductivity of the stem. The recovery of the normal current was slow, and incomplete yet at IV. This was at about 5 P. M. Two hours later the plant was found to have a normal current downward. A forced current in this direction gave

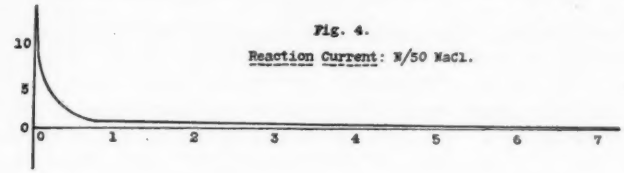


Fig. 4.

Reaction Current: N/50 NaCl.

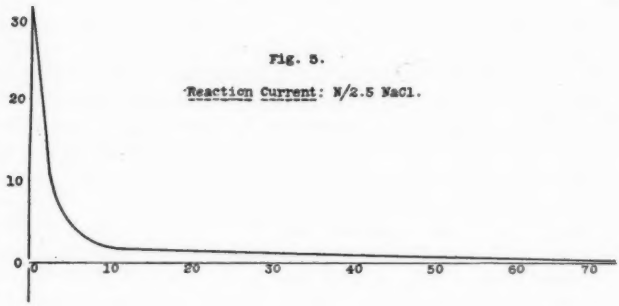


Fig. 5.

Reaction Current: N/2.5 NaCl.

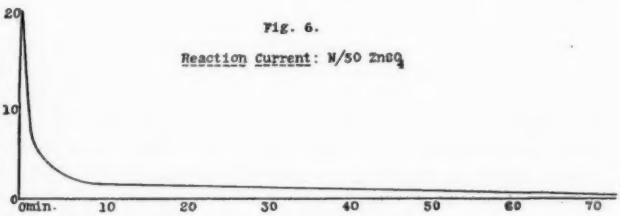


Fig. 6.

Reaction Current: N/50 $ZnSO_4$

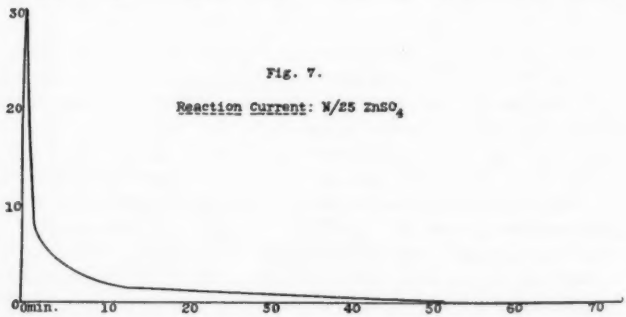


Fig. 7.

Reaction Current: N/25 $ZnSO_4$

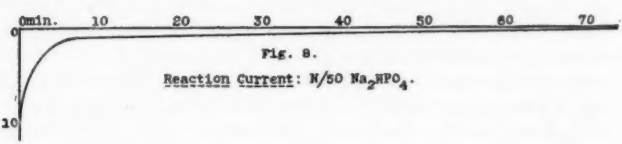


Fig. 8.

Reaction Current: N/50 Na_2HPO_4.

the reaction at V. Since the plant had been resting during the hour before and the hour after sunset, it was thought that its reversal of normal current might be due to a change in physiological activity. Accordingly, a little later in the season a plant was tested for daily variations in its normal current. Fig. 13 shows its behavior in this respect for the first 54 hours after it was removed from the greenhouse to the laboratory. The sudden drop in temperature caused the plant-current to turn downward for a few hours, after which it flowed upward with increasing intensity until about 6 P. M. At 9 A. M. next day the current was downward. At noon no current was present, and then it was upward until 6.30 P. M. With minor variations for temperature-change, this day's record was found to be quite typical. Other experiments also point to the conclusion that when plants are physiologically active the normal current is upward, while in the comparatively passive plant this current is either wanting or downward.

Figs. 14*a* and 14 show the results of a series of experiments to test the effects upon the normal E.M.F. of mechanical injury and heat. The plant showed the usual upward current at 2 P. M. When the stem was heated at the lower contact to 35° C. the intensity of the upward current was increased. Upon cooling this terminal to the normal temperature and heating the upper one the current was reversed, as shown at I. On cooling this terminal the current came back almost to its original condition. Next, light pressure was applied to the stem at the point of contact, with resulting current toward the other contact through the stem, as shown at II in the figure. Piercing the stem near the contacts with a platinum needle produced no perceptible effects on the E.M.F. At III, the terminal points were alternately heated to 40° C. for a very short time. After this test the normal current was reduced to zero. The stem was then crushed midway between contacts with no indication of current. At IV the stem was crushed at the contact, showing a momentary E.M.F. through the stem, away from the point of injury. Heat to 40° C. gave the reaction at V, the current always flowing through the stem from the point of high temperature.

The stem was now completely crushed between the contacts, but no E.M.F. was shown while this was being done. Heat to 40° C. gave VI. At VII the usual battery current was applied. The reaction indicates a higher conductivity than in a normal stem. This is readily explained by the fact that in the crushed stem the intercellular spaces are filled with the cell-sap, which thus forms a conductor of less specific resistance than is met with in the normal condition of the plant, where the electric current must pass through cell walls and films of living protoplasm. At VIII the forced current was repeated, and the reaction indi-

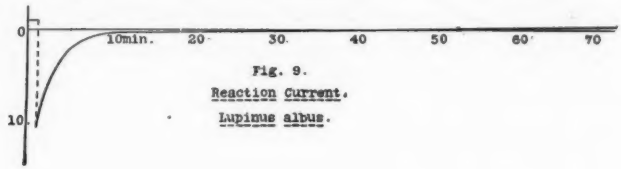


Fig. 9.
Reaction Current.
Lupinus albus.

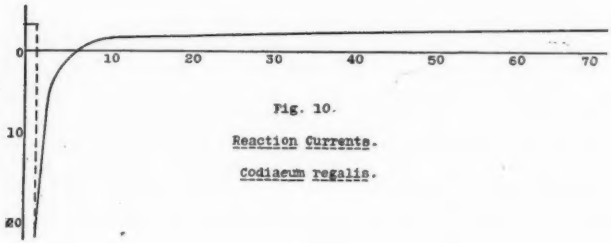


Fig. 10.
Reaction Currents.
Codiaeum regalis.

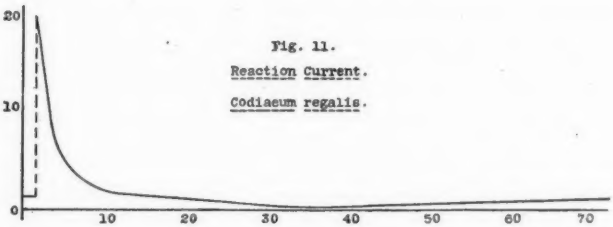


Fig. 11.
Reaction Current.
Codiaeum regalis.

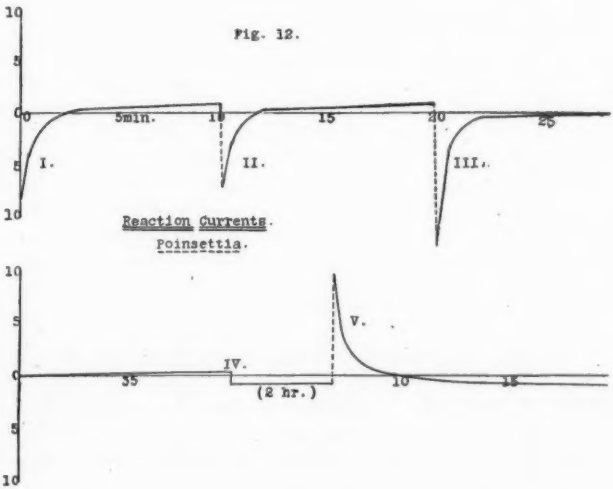
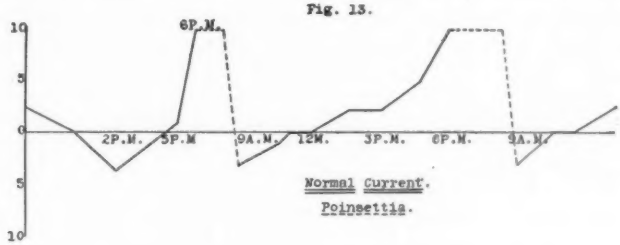


Fig. 12.
Reaction Currents.
Poinsettia.

cates a still further reduction of the resistance. At IX the lower contact point of the stem was heated to ignition over an alcohol flame. The maximum current appeared when the

Fig. 13.



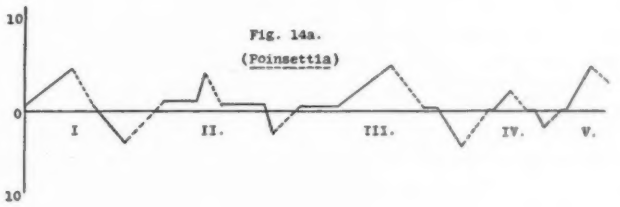
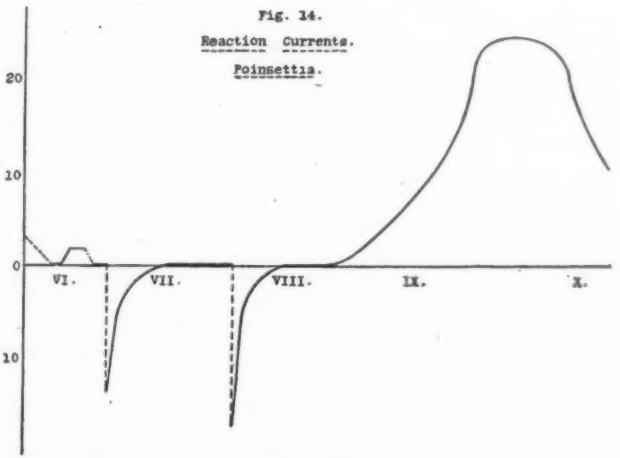


Fig. 14.



stem was about two-thirds burned off, after which the current decreased slowly until the stem broke under its own weight at X in the figure.

The explanation of all these phenomena comes naturally within the domain of physical chemistry. Thus, the applica-

tion of heat to any part of the plant,—other conditions being normal,— will invariably increase the physiological activity of that part, so long as the temperature does not exceed a certain optimum degree. Moreover, the increase of temperature is attended by, or rather is due to, an increased kinetic energy of the atoms. But any acceleration of the motions of the atoms in a solution is normally attended by a corresponding increase in dissociation and electrical conductivity. In like manner, slight pressure on the walls of any plant-structure is attended by violent molecular displacements through the cell walls and protoplasmic films. This, also, destroys the kinetic equilibrium of atomic relations, and a local E.M.F. is the natural consequence. Temperatures above a certain maximum kill the protoplasm, and the "normal plant-current," which is an index of physiological activity, necessarily disappears. We have now to deal with dead protoplasm, and the only difference in reaction worthy of note is a slight decrease in specific resistance of the tissues, due to a more ready diffusion of the conducting liquids.

These few experiments, while they are of a preliminary and very general character, seem to point with a fair degree of certainty to the following conclusions:

1. The functional activities of a plant give rise to differences of electrical potential in its parts.

2. The intensity and relative sign of these differences depend upon the physiological condition of the plant, as well as upon its electrical conductivity.

3. The normal E.M.F. in a plant may be modified in intensity or direction by brief application of forced currents. This appears to be due in part to a change in resistance, and in part to a modification in the vital activity of the protoplasm.

4. Slight mechanical injuries do not perceptibly modify the normal current.

5. Extensive mechanical injuries or high temperatures destroy the normal current, but do not modify the reaction current, except by a slight increase in the conductivity of the tissues.

6. Extensive injuries to a plant excite an E.M.F. spreading from the point of injury through the tissues.

7. "Reaction currents," in the sense in which this term is used in this paper, depend but little, if at all, upon the vitality of the plant, and can be duplicated in non-living substances.

Harvard University,
Cambridge, Mass.

ART. IX.—*The Ionization of Water Nuclei;* by C. BARUS.

1. *Introductory.*—In my report to the Smithsonian Institution (August, 1902) and elsewhere,* I pointed out the desirability of further investigations on the Lenard† effect. While my work in this direction was in progress, a paper due to J. J. Thomson appeared, covering similar ground. Nevertheless I shall venture to publish the following results since the subject is looked at from a somewhat different point of view, obtained

1

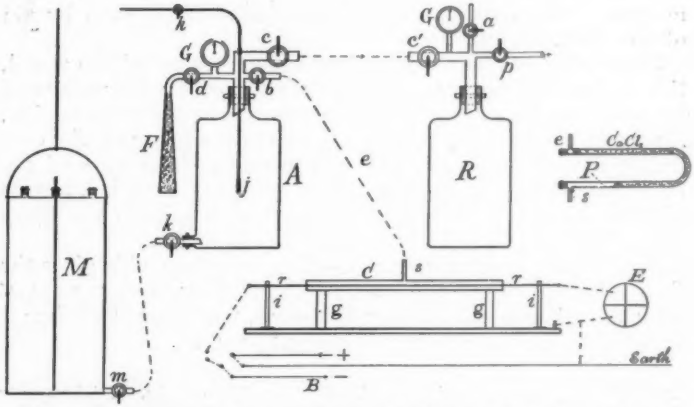


FIGURE 1. Apparatus for comparing nucleation and ionization; *A*, coronal chamber; *R*, exhaustion reservoir; *M*, Mariotte flask; *C*, tubular condenser; *P* (to be inserted in the conveyance tube, *e*) phosphorus ionizer; *G*, *G'*, vacuum gauges; *F*, cotton filter; B, storage battery terminals. Tubes *p* to suction pump; *a*, to atmosphere; *c*, *c'*, for exhaustion; *e*, for conveying the nuclei into the condenser; *d*, for filtration; *h*, from the hydrant. Extremely fine jets of water shoot out from the needle pricked lead pipe, *j*. Supports *g*, *g* are metallic; *i*, *i*, insulating.

from coronal and other measurements. My chief purpose, however, is to find whether as a result of Thomson's‡ remarkable discovery of radio-activity associated with water nuclei, the theory given in my "Experiments with Ionized Air"§ is to be abandoned. The experiments of this paper show, I think, that this is not necessary. They contain, it seems to me, an interesting confirmation of the views stated in the third

* Science, xvi, p. 633, 1902.

† Lenard, Wied. Ann., xlvi, p. 584, 1892.

‡ J. J. Thomson: Experiments with Induced-radio-activity of Air, and on the Electrical Conduction Produced in Gases When they Pass through Water; Phil. Mag. (6), iv, p. 352, Sept., 1902.

§ Smithsonian Contributions, No. 1309, 1901.

chapter of my memoir, and lead to an explanation of the electrical behavior of water nuclei, so far as it is here in question, which is free from new hypotheses.

2. *Apparatus.*—If in the receiver, or condensation chamber, A, the cock, b, is joined with s by a metallic pipe, e, leading directly to the tubular condenser C (radii 1·05 and ·32^{cm}, length, 50^{cm}), the apparatus takes the form of figure 1, adapted for measuring the initial ionization of the nuclei. If the cocks k and d (filter) are closed and the fine radial jets are put in action by opening the water faucet, h, the charged air is gradually expelled through b as the water level in A rises. When an efficient jet is used the rate is usually about $dV/dt=2$ liters/minute. This velocity may be increased or diminished by aid of the flask, M, attached at k.

Since the jets from j impinge on the walls* of the vessel, this is kept uniformly moist, or better, coated with water and therefore continually put to earth by the hydrant connection. Similarly the pipe, e, leading to the outer coating of the condenser is with this continually put to earth. The core of the condenser, insulated by long hard rubber supports, i, i, retains charge well, even at high potentials and in spite of the damp gases, because of the remoteness of the supports.

3. *Results—Initial Charges.*—The following table gives the data obtained when the nuclei generated by the spray are *at once* passed into the tubular condenser, whose inner surface is charged as stated, the outer being put to earth.

TABLE I.—Ionization of water nuclei. $dV/dt = 2$ liters/min. Total capacity 72^{cm}. Deflections of electrometer s in the lapse of time given in the chart, curve No. 1.

Electrometer charge.	Insulation before.	a	Insulation after.	δs cm/min.
+ at	$a = ·013$	·338	$a = ·010$	7·9
20 volts		·490		7·1
− at		·072		3·2
20 volts	$a = -·020$	·091	$a = ·002$	3·8
		·108		4·0
		·124		4·0
+ at	$a = ·022$	·223	$a = ·015$	7·9
20 volts		·335		7·8
		·498		7·1
		·872		

Similar observations are given in the chart, curves 2 and 3, for higher potentials. The first observations are usually low, for the nuclei do not at once fill the condenser. The last observations are often high, § 14.

* Charged nuclei are also produced from jets impinging on a surface of water, without a solid obstacle, or when jets shatter each other. The efficiency, however, depends on the degree of comminution.

The method consisted in testing the insulation of the condenser, immediately before and after the introduction of water nuclei. The observations give the deflections, s, of the electrometer in cms. after intervals of 1 min., $\frac{1}{2}$ min., and 1 min., in each of the cases, respectively. The conduction, $a=\delta(\log s)/\delta t$, is computed by assuming Ohm's law; but in case of the medium of water nuclei, it is seen at once that Ohm's law does not apply, and that the conduction, a, increases enormously as the charge on the condenser vanishes. The average value of the conduction is quite of the order of values found for phosphorus nuclei elsewhere, under similar circumstances. As the data in the table show a for successive minutes, its variation in the last series is from ·223 to ·872 in 3 minutes.

Since 2·3 $aC = 1/R$, where $C = 8/10^{11}$ farads, is the capacity of the condenser and appurtenances, the initial and final resistance, R, would be

$$R = 25\times10^{9} \text{ and } R = 6\times10^{9} \text{ ohms.}$$

It follows then that if the equation of the current be taken, or $i = n(U+V)e(E/l)$ in the usual notation, the number of nuclei, n, increases as the potential difference, E, diminishes. The same is true for the negative current with a smaller coefficient.

These and other results for the conduction, a, become more interesting if the electrometer deflections are charted graphically in relation to time as in the annexed figures 1, 2, 3. It is thus seen that the current is surprisingly constant, while the initial potential difference of about 20 or 40 volts gradually quite vanishes. In explanation, one may suppose that the number of ionized nuclei varies inversely as the potential difference, i. e., $nE=$ const.

It is apparently more simple, however, it seems to me, to assume that the velocity of the nuclei is independent of the potential gradient, each nucleus having its own specific velocity in the presence or the absence of an electric field, while the number of nuclei is practically constant,—the point of view taken in my earlier work.* The different currents for positive and negative charges in the condenser are then due to the known excess of negative nuclear charges. This view is actually *broader* (§§ 4, 14) than at first sight it seems, for it includes the case in which the velocity of the nucleus and the velocity of the ions or charges are the same function of the potential gradient in the condenser.

4. *Working Hypothesis and Constants.*—Supposing that the current is independent of the electromotive force of the condenser as just stated, and that k is the specific velocity of the nuclei (due to unsymmetrical bombardment, as heretofore

* Experiments with ionized air, l. c., chap. v, p. 69.

assumed), the radial current, di, at the element dl will be

$$di = 2\pi\,(r_2 + r_1)\,nke\,dl,$$

where r_2 and r_1 are the external and internal radii of the con-

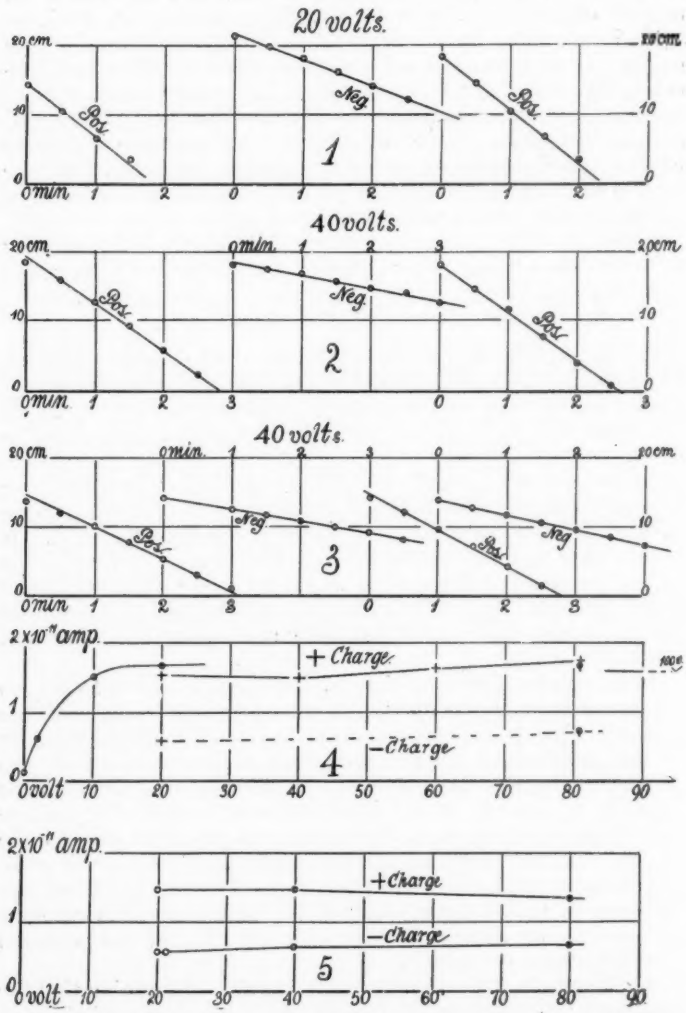


CHART 1.—Curves 1, 2, 3, electrometer deflection (leakage) after consecutive half minutes, for different charges and potentials in the condenser.

Curves 4, 5, radial currents (amperes) for different charges and potentials (volts) in the condenser.

denser of length, l, n the nucleation (number per cub. cm.), k their effective velocity and e the charge on each.

The value of n, for the case that decay of ions occurs merely by absorption of the charge at the walls of the cylinders, is $n = n_0 \epsilon^{-2kl/v(r_2-r_1)}$ where v is the velocity (cm. / sec.) of the nuclei-laden air in the direction of the axis of the cylinder.

Here, however, a sharp distinction must be made between the fate of the nuclei and of their charges. The latter are absorbed, producing current. The water nuclei, so far as evidence from coronas goes, are not appreciably absorbed. With phosphorus the absorption of nuclei could be independently proven for the fresh emanation. It failed, however, for very wide tubes, implying stale emanation. Hence, after integration, if the leakage of the condenser is dE/dt and its capacity C,

$$C(dE/dt) = \pi e v n_0 (r_2^2 - r_1^2)(1 - \epsilon^{-2kl/v(r_2-r_1)}).$$

Since, $v = 16{\cdot}7\ V/\pi(r_2^2 - r_1^2)$, if V are the liters of nucleated air fed into the condenser per minute, the equation becomes,

$$dE/dt = \frac{16{\cdot}7\ n_0 e V}{C}(1 - \epsilon^{-376\,kl(r_2+r_1)/V}). \qquad (1)$$

The length of the condenser enters only into the exponential quantity, and the results are the same if l/V is constant. Hence so long as the exponential quantity vanishes, k may be any function of the potential gradient, a result which gives the equation much broader significance than appears from the premises.

To find the value of the parenthesis, it may be tested by assuming $k = 1{\cdot}5$ cm. / sec., the value* for ionic velocities. Hence the constants are as follows:

$l = 50$ cm.	$V = 2$ liters / min.
$2r_2 = 2{\cdot}10$ cm.	$k = 1{\cdot}5$ cm / sec.
$2r_1 = {\cdot}64$ cm.	$e = 2{\cdot}3 / 10^{10}$ coulombs,

and therefore the exponential quantity here vanishes. The equation now reduces to

$$dE/dt = 16{\cdot}7\ n_0 e V / C,$$

where n_0 is the initial number of nuclei entering the condenser, e the charge of each, V the liters of nucleated air supplied per minute, C the capacity of the condenser. The current is therefore independent of the length and radii of the condenser and the velocity of the nuclei. This will still be true of k in the two differential equations for di and dn above, is the same

* Experiments with ionized air, chapter iii. The value of k for water nuclei is much smaller than the datum assumed, as will be specified below.

function of the potential gradient $E/(r_2 - r_1)$; and so long as the value of k has not been directly found, the assumed small value of the exponential term is merely admitted for argument but will be further interpreted in § 14.

The additional constants needed are

$$C = 72{\cdot}5/9 \times 10^{11}$$
$A = {\cdot}91$, the voltage factor of the electrometer.

The table then gives as the currents,

$$dE/dt = {\cdot}120 \text{ volts/sec., for the positive charge,}$$
$$= {\cdot}059 \quad \text{“} \quad \text{for the negative charge;}$$

so that the average current, ·090 volt/sec., may be taken as due to the ions, positive and negative, but neutral as a whole, while the observed values of dE/dt are due to the excess of negative ions. Hence

$$n_0 = \frac{(dE/dt)\,C}{16{\cdot}7\,e\,V} = 9{\cdot}7 \times 10^5$$

The number of ionized nuclei entering the condenser is thus estimated at about a million per cubic centimeter, if each nucleus carries one electron, and it will probably be indefinitely larger, if the nuclei-laden air-current V is swifter; for the charge is rapidly lost in the conveyance tube e between the receiver A and the condenser C, fig. 1.

5. *Comparison with Coronas.*—The number of ions thus computed is excessive, particularly in view of the number of nuclei obtained from the order of the first corona. The previous investigations show that this is number 9 in my series, and corresponds to about 5,000 nuclei.

Several inferences are thus suggested: either the charge of each nucleus is about 200 times larger than the value assumed, i. e., each nucleus on entering the condenser brings 200 electrons; or nuclei are lost at the outset at an enormously rapid rate, so that only ·005 of the original number remain when the first condensation is made; or finally, that each nucleus emits 200 electrons as a result of the peculiar radio-activity inferred by J. J. Thomson (l. c.). The second view may be disproved by direct tests. My own preferences in this paper are for the first, for the reasons to be given in the sequel.

6. *Potential of the Nucleus.*—Assuming the nuclei to be 10^{-5} cm in radius (they are probably smaller), their capacities will be $10^{-5}/9\times10^{11}$ farads. Hence the potential of each is

$$V = 4{\cdot}1 \text{ volts.}$$

With the particles present even to the extent of a million per cub. cm., this charge would be easily retained, since it

requires about 1,500 volts to spark across the intervening space of ·02^{cm}. With only 5,000 or 6,000 particles present the condition would be enhanced over five times.

There seems then to be no reason for departing from the point of view in this paper even if the number of nuclei computed from coronas is somewhat low. As the nuclei neither vanish coincidently with the ions nor are present in similar orders of numbers, a sharp distinction must be drawn between nuclei and ions.

7. *Behavior of Phosphorus.*—It will be interesting to insert, by way of comparison, the corresponding treatment of phosphorus nuclei. The last equation for n cannot here be assumed, for Ohm's law is roughly obeyed. The conductions obtained above depend on the intensity of the ionizer, and on the air current, V, and the conduction $a=·3$, found elsewhere, may be assumed for $V=2·5$ liters/min., as an average case.

The current must here be written

$$di=2\pi(r_2+r_1)kne\frac{E}{(r_2-r_1)}dl,$$

for the element, dl, while the number of nuclei, n, follows the same equation as above, if the spontaneous decay of nuclei in the lapse of time is ignored. The exponential term may again be omitted. The full result* after integration is

$$2·3\,a=-(dE/dt)/E=-(ds/dt)/s=\frac{16·7\,Ven_0}{(r_2-r_1)\,C}(1-\epsilon^{-·377\,kl(r_2+r_1)/V}) \quad (2)$$

Hence,

$$n_0=\frac{(r_2-r_1)\,C\,2·3\,a}{16·7\,Ve}$$

The constants are

$r_2=1·05$, $r_1=·32$, centim.,
$a=·3/60$, (referred to seconds)
$C=8/10^{11}$ farads,
$e=2·3/10^{19}$ coulombs,
$V=2·5$ lit/min.

Thus

$$n_0=·7\times10^5.$$

In my former work† with a condenser of totally different

* Experiments with ionized air, p. 67.

† Experiments with ionized air, p. 69; cf. pp. 53, 91, 93. Owing to an error in estimating the capacity of the electrometer, the results there given are too low and have since been corrected as in the text. This makes the phosphorus emanation richer in nuclei than air ionized by the X-rays, a condition otherwise probable.

dimensions ($r_2 = \cdot 60$, $r_1 = \cdot 32$, $l = 50^{cm}$) the result was $\cdot 6 \times 10^5$. The data for complete saturation were (after correction)* about 3×10^5, agreeing fairly well with the present cases where the ionization is necessarily undersaturated, because of the influx tube.

8. *Evanesence of the Charges of Water Nuclei.*—The same remarkable contrast between the initial charges and the subsequent charges on the nuclei will now be observed, if only a little time is allowed to intervene, that was already pointed out for phosphorus. Table 2 refers to nuclei produced in the receiver *A*, figure 1, by allowing the accumulating water to run off by the cock, *k*. They were then conveyed to the condenser *C*, about five or ten minutes later, by aid of the Mariotte flask, *M*. The conduction is enormously reduced, though for positive charges in the condenser it is greater than for negative charges, showing that an excess of negative nuclei has persisted.

TABLE II.—Ionization of water nuclei after 5–10 minutes. $dV/dt = 2 \cdot 5$ lit/min. Capacity 72cm.

Charge.	Insulation before.	a.	Insulation after.	Corrected a.
+ at 30 volts	....	·019	$a =$ ·009	·010
— at 30 volts	....	·005	$a = -$·002	·007

In Table 3 the data refer to nuclei which were left in the vessel *A* for about one hour after they were produced. The original ionization has all but vanished; nevertheless there is still an excess of negative nuclei, as shown by the greater leakage of positive charges in the condenser. If negative nuclei had been more rapidly precipitated in the intervening hour in *A*, the reverse should have been the case, there should have been an excess of positive nuclei, and negative charges in the condenser should vanish more rapidly.

TABLE III.—Ionization of water nuclei, 1 hour after production. $dV/dt =$ 2·5 lit/min.

Charge.	Insulation before.	a.	Insulation after.	Corrected a.
+ at 20 volts	....	·013	$a =$ ·009	.004
— at 20 volts	....	·003	$a =$ ·001	·002

Tested for coronas, after about one hour, 1,000–2,000 were left, or about 1/3 of the original 5,000, a result quite out of proportion with the loss of ionization. The electrical and condensational phenomena are thus again distinctly separated.

9. *Results with an Elliott Electrometer.*—For reasons which need not be stated here, the electrometer of modern type above, in which the charge is imparted to the needle through the suspension, notwithstanding its sensitiveness and low capacity, is not adapted for further experiments. Accordingly the data of the following table were obtained with an ordinary electrometer, with the quadrants permanently charged with a water battery. The core of the tubular condenser communicated with the needle. This adjustment was chosen because the leakage here was relatively smaller, though the high capacity of needle, jar and condenser is unfavorable to sensitiveness. The table contains results in which the potential of the core of the condenser was altered in steps of one half. Care was taken to determine the insulation immediately before and after each measurement with the nucleated medium. The leakage was always greater at the beginning than at the end, which is the usual phenomenon of absorption and release of charge in the insulators. If any trace of radio-activity occurred, it would be obscured by this phenomenon.

The results of these observations may be summarized as follows:

TABLE IV.—Charges of water nuclei. $dV/dt = 2$ lit/min. Capacity 409^{cm}. Deflection of the electrometer, s.

	Leakage ds/dt per 2^m				
Electrometer charge.	Before. cm.	During nucleation. cm.	After. cm.	Current $C(dE/dt)$ $\times 10^{11}$. amperes.	n_0 $\times 10^{-6}$.
+ at 81 volts	·13	·64	·09	1·33	1·72
− at 81 volts	·17	·39	·06	·67	·87
+ at 40 volts	·10	·67	·06	1·47	1·91
− at 40 volts	·11	·34	·05	·64	·84
+ at 20 volts	·08	·63	·03	1·45	1·89
− at 20 volts	·06	.27	·02	·57	·74

From these, since $n_0 = (dE/dt)\ C/16{\cdot}7\ e\ V$, the results of the last column follow, giving for the mean currents

at 81 volts $n_0 = 1{\cdot}3 \times 10^6$
at 40 $1{\cdot}4$
at 20 $1{\cdot}3$

These values of n_0 are somewhat greater than the preceding ($n_0 = 10^6$), but the difference is at once referable to the gradually increasing size of the holes in the lead jet as the result of long spraying. Slight changes in V lit./min. are now of importance because of the rapid loss of the charges in the influx tube of the condenser.

Whereas the current for positive charges decreases with the potential, the current for negative charges increases; but this, too, is due to incidental reasons of the kind mentioned. Seen in the light of the results preceding and following it, the general evidence of the table is rather to the effect that the current in the condenser is constant, independent of the electromotive force when the gradient exceeds about 20 volts per radial centimeter.

These results are marked 5 in the chart.

10. *Further data.*—A series of results quite similar to the last but with a more sensitive electrometer, is given in the next table. As a rule positive charges were taken in succession, though a number of incidental data accompany the table. The insulation of the electrometer was found before and after each of the measurements with nuclei. Having been taken on different days and not in a single sweep, the results cannot be quite coincident, because of jet differences, water pressures, etc., as already stated.

These observations may be summarized as follows:

TABLE V.—Charges of water nuclei. $dV/dt = 2$ lit/min. Capacity 409^{cm}. Electrometer deflections, s.

Electrometer charge.	Leakage ds/dt per 2^{min}. Before cm.	During nucleation. cm.	After cm.	$C(dE/dt)$ $\times 10^{11}$ amperes.	n_0 $\times 10^{-6}$.
+ at 81 volts	·21	1·88	·17	2·17	2·2
− at 80 volts	·23	·98	·19	·95	1·0
+ at 81 volts	—	1·98	·22	1·74	2·3
+ at 60 volts	·22	1·79	·13	1·62	2·1
+ at 40 volts	·11	1·55	·04	1·48	1·9
+ at 20 volts	·05	1·57	·00	1·54	2·0
− at 20 volts	·13	·68	·05	·59	·8
+ at 20 volts	·08	1·56	·02	1·51	2·0
+ at 20 volts	·08	1·46	·05	1·66	2·2
+ at 10 volts	·02	1·29	·00	1·51	2·0
+ at 2 volts	·01	·52	·00	·61	·8
± no charge	·00	·11	·00	·13	·2
+ at 100 volts	·16*	·88	·12	1·59	2·0

Corona on immediate condensation: white, crimson, green, being No. 9 with 5000–6000 nuclei per cm^3.

* Smaller electrometer factor.

The currents are given in the chart and marked 4. They show that above 10 volts the currents are practically constant, remembering that any change in V due to water pressure, etc., will convey the nuclei more rapidly into the condenser, and from their exceedingly rapid decay at the outset, the currents will necessarily be variable. Below 10 volts the current decreases with the potential but remains quite appreciable even when the potential is zero with the absence of charge in the condenser. The two observations made for the negative charge indicate similar relations, when taken in connection with the preceding results.

The average number of nuclei in those cases where positive and negative charges were observed are found to be

$$\text{at 81 volts} \quad n_0 = 1{\cdot}4 \times 10^6$$
$$\text{at 20 volts} \quad n_0 = 1{\cdot}6 \times 10^{6-}$$

results slightly larger than the preceding, again due to further enlargement of the holes of the jet, whereby fresher nuclei are put into the condenser.

The table states that the most advanced corona obtainable did not exceed No. 8 or 9 of my series,* throughout the whole of the work. It makes little difference whether the corona is taken instantly or a few minutes after the jet is shut off. The number of nuclei, therefore, is constant throughout the experiments.

Summary and inferences.

11. *Charge and Conduction.*—The data have shown that positive as well as negative charges are dissipated by water nuclei, immediately after they have been produced, and that the ionization, if it may be so called, is quite of the order of that of phosphorus. After being stored but a few minutes, the nucleation loses all but a few per cent of this property of conduction, behaving in this respect again like phosphorus nuclei. The number of nuclei does not appreciably vary in the same time. The character of the ionization (whether positive or negative nuclei are in excess) remains intact, so long as it can be observed. Hence the large initial and the eventual very small conduction (a few per cent of the original value) may be regarded as two successive phases of a single continuous phenomenon, either of charge or ionization or conduction. It seems to me therefore that it is not necessary to distinguish the initial charges from the initial ionization. The experiment as a whole shows an *attenuation of the Lenard effect*, continuously, through infinite time. One is at liberty to refer the conduction either to charged nuclei or to ionized nuclei, unless some

* Phil. Mag. (6), iii, p. 80–91, 1902.

distinctive definition is adopted. Both occurrences are similarly reduced. The present case of river water is one in which there is an excess of negative over positive nuclei. In other cases (pure water) the reverse may be the case, or again there may be an absence of an excess of either sign. If the nuclei were without charges, however, the medium would not conduct (§ 14). In a condenser positive or negative charges are soonest dissipated according as there is excess of negative or positive nuclei in the medium, respectively.

12. *Number of Electrons.*—Assuming each nucleus to have its own specific velocity, independent of the potential gradient of the electric field, and to carry one electron, the number of nuclei per cub. cm. was preliminarily computed as $n_0 = C(dE/dt) = /16{\cdot}7\, eV$, where C is the capacity, dE/dt the leakage of the condenser and appurtenances in practical units, e the charge in coulombs on each, and V the volume of nucleated air, in liters, entering the condenser per minute. Attributing the larger current from positive charges in the condenser to an excess of negative ions, the average current was assumed to represent the case of an equal number of ions of either sign, i. e., when the excess of negative ions has been removed. The values so obtained for this average current if each nucleus carries but one electron (which cannot be the case) are

$$n_0 = 1{\cdot}0 \times 10^6$$
$$1{\cdot}3$$
$$1{\cdot}5$$

The increase is due to the gradual wear of the jet, whereby fresher nuclei are conveyed into the condenser, as explained.

13. *Number of Nuclei.*—With this large number of ions, the number of nuclei as estimated from the coronas is in sharp contrast. There being less than 10^4 and more than 10^3 original nuclei, the charge of each must be greater than 100 and less than 200 electrons, agreeing that the whole charge is carried by the nuclei, for which there is good reason as the currents and the number of nuclei increase together with the efficiency of the jet.

If each nucleus is to carry the charge stated, its potential will still be of relatively small value, as was shown in § 6.

14. *Ohm's Law.*—For potential differences above 10–20 volts or gradients of 15–30 volt/cm., the currents in the condenser are roughly constant. Below this the current begins to decrease with the gradient, without, however, quite vanishing, even when the potential difference is zero. In the above tables, or chart No. 4, for instance, the average current for a charge at

10 volts, gave $n_0 = \cdot 9 \times 10^6$
2 $\cdot 5$
0 (negative only) $\cdot 2$

J. J. Thomson (l. c.) accounts for these phenomena by a bold and original hypothesis that each nucleus is superficially polarized with positive oxygen and that negative corpuscles are, as a consequence, projected from it into the medium. A constant current independent of the electromotive force results when as many corpuscles are produced per second as are consumed by the current.

To me it seems, however, that the hypothesis of this paper points to a simpler explanation.

In the first place the equations used in the case of water nuclei

$$dE/dt = \frac{16 \cdot 7\ n_0\, e\, V}{C}(1 - \epsilon^{-\cdot 377\, kl(r_2+r_1)/V}) \ldots (1)$$

and in case of phosphorus nuclei,

$$(dE/dt)/E = \frac{16 \cdot 7\ n_0\, e\, V}{C(r_2 - r_1)}(1 - \epsilon^{-\cdot 377\, kl(r_2+r_1)/V})\frac{U}{k} \ldots (2)$$

contain an exponential factor, which is increasingly more important when k is small. Furthermore in equation (1), k cancels out in the coefficient of the parenthesis, and may therefore be any function of the potential gradient within the condenser. Equation (1) is thus true, no matter whether k is a function of $E/(r_2 - r_1)$ or not, and an equation involving both (1) and (2) may be written, if $(1 - \epsilon^{-a})$ stands for the exponential factor,

$$dE/dt = \frac{16 \cdot 7\ n_0\, e\, V}{C}\ \frac{1}{1 + k/(UE/(r_2 - r_1))}\ (1 - \epsilon^{-a}) \ldots (3)$$

where U is the combined velocity of the ions or charges in the unit electric field, and k is the effective velocity of the nuclei. In other words, k is now replaced by $k + UE/(r_2 - r_1)$.

Hence if the value of k is large as compared with $UE/(r_2 - r_1)$, i. e., if the nuclei have a specific velocity large in comparison with the ionic increment due to the field, that is if the nuclei are very small, equation (2) may be assumed, as was done for phosphorus nuclei.

If the value of k is small as compared with $UE/(r_2 - r_1)$, i. e., if the nuclei are relatively large, then equation (1) is approached, as was found to be the case for water nuclei. The full value of the exponential term is

$$1 - \epsilon^{-\cdot 377\,(r_2+r_1)(k + UE/(r_2-r_1))\,l/V},$$

and from the small value of k under consideration, it depends

essentially on E. Hence if the ionization is neutral (equality of positive and negative ionization or charge), the current will vanish with the potential gradient or with the charge in the condenser.

It is next in place to show that the exponential factor soon becomes constant and equal to one. This is done in the following table by direct computation, using the constants already summarized.

$k+UE/(r_2-r_1)=$	$1-\epsilon^{-a}=$
·001 cm./sec.	·013
·010	·121
·100	·736
1·000	1·000

Hence when the total nuclear velocity approaches the usual values of ionic velocity in air (1·5 cm./sec.), the current is constant and

$$dE/dt = 16{\cdot}7\ n_0\, e\, V/C.$$

Thus the character of the curve given in the chart is actually predicted without an assumption as to radio-activity.

It is further pointed out by the equation that uncharged water nuclei cannot conduct appreciably, seeing that they owe their effective velocity to the field, which becomes inactive in the absence of charge.

Finally the velocity of the water nucleus under an assumed probable size may be computed. The resistance to motion at velocity v, of an infinitely small sphere of radius R in air of viscosity μ is $6\pi\mu Rv$ dynes (Kirchhoff's Mechanik, lecture 26, § 4). The pull of the field on the charge e is equal to this, whence

$$v = Ee/(6\pi\mu R(r_2-r_1)).$$

If the nuclei diffuse appreciably, R is smaller than 10^{-4} cm. which would follow for subsidence, and R may then be estimated at 10^{-4} cm.; while $\mu = 2\times10^{-4}$, $r_2-r_1 = {\cdot}73^{\text{cm}}$, $E = 20/300$ and $e = 200\times7\times10^{-10}$ electrostatic units, if each nucleus carries 200 electrons. Hence

$$v = 3{\cdot}4 \text{ cm./sec.}$$

which is about ·12 cm./sec. in the field of one volt/cm. This value is actually very large as compared with the values which I found (§ 15) for the velocities of water nuclei in the absence of a field, but it is naturally dependent on the uncertainty of R. I shall waive the subject here, as I propose to return to it more specifically elsewhere.

15. *Comparison of Phosphorus and Water Nuclei.*—Between phosphorus and water nuclei there is in the first place the

essential difference that whereas the current in the first case obeys Ohm's law, roughly, it does not do so in the second, being more and more independent of the electromotive force as E increases above about 15 volts per cm. Corresponding to this the coronas for water nuclei terminate with the ninth in my series (5000 nuclei, § 5), whereas in case of phosphorus they go to indefinitely higher orders beyond the first (3×10^5 nuclei) in the series. Parallel to this there runs a difference in the size of nuclei. The inference is warranted that phosphorus nuclei are small as compared with water nuclei, inasmuch as the latter owe their origin to mechanical conditions (evaporation from gross fog particles), while the phosphorus nuclei arise under chemical conditions and molecular dimensions.

Finally, in direct measurements made by the steam jet method (Experiments with Ionized Air, chap. iii), the velocity of the phosphorus nucleus in the absence of an electric field was actually shown to be of the order of ionic velocities in air, while with experiments* since made with water nuclei ·001 to ·01 cm. / sec. are average orders of values depending on the concentration of the solution. Experiments are in progress to determine the velocity, k, with the identical water nuclei under discussion in the above paragraphs; but the data in hand are sufficient to warrant the use made of the hypothesis.

In other respects there is great similarity in the behavior of the two types of nuclei. The enormous charges or ionizations at the beginning vanish to a residuum of a few per cent in a few minutes, if confined by a receptacle, while the nuclei are not affected either as to number or condensational properties by the presence or absence of the primitive charge.

16. *Condensational effect of Negative Ionization.*—In none of the experiments, either with the neutrally ionized phosphorus emanation (where the ionization was tested after partial condensation and subsidence of fog particles) nor with the negatively ionized solutional nuclei is there evidence that negative ions are more active as condensation nuclei than positive ions. The electrical conditions vanish to a few per-cent almost at once, while the nuclei are relatively permanent. Experiment makes it improbable that the small residuum of charge can have any appreciable bearing on condensation; witness the identical behavior of water nuclei when used immediately after production and highly charged, and when used some time later, after the charge has certainly left them. Moreover the charges vanish proportionately, which they would not do if the negative ions had a greater affinity for

* This Journal (4) xiv, p. 225, 1902; cf. forthcoming memoir on "The Structure of the Nucleus," Smithsonian Contributions, 1902.

water vapor. An initial excess of positive or negative ions means a corresponding excess in the small electrical residuum.

Regarding Wilson's famous experiment, I have already expressed my belief that it is the unavoidable synthesis in a region of intense ionization that furnishes the nucleus, and that such synthesis must be different on the acid and alkaline side of a battery.* The same explanation would apply to nuclei obtained from any kind of radiation.

17. *Induced-radio-activity.*—In none of the experiments was observable radio-activity imparted to the core of the condenser. The insulation determined before and after the passage of the nucleated medium showed greater leakage in the first than in the second instance, whether the charge was positive or negative. This corresponds to the usual electric absorption of insulators. If radio-activity had been present, the latter insulation should have been worse than the earlier, instead of the reverse case, invariably observed.

True the potentials did not exceed 100 volts and in J. J. Thomson's experiments a Wimshurst machine was needed to bring out the radio-active effect. But if within the limits of the above experiments no such effect was demonstrable, I do not see that one is at once at liberty to assume it; for it is quite possible that the enormous potentials of the electric machine introduce conditions which have no bearing on the work of the above pages. One may imagine, for instance, that a compound of metal and water nuclei may be stable in presence of a strong negative field, but unstable in the absence of the field, just as I suppose that a compound of oxygen and phosphorus is stable in presence of excess of phosphorus (close to the surface of the phosphorus) but unstable in excess of air (away from the phosphorus), and that the dissociation is accompanied by ionization. To this extent I have ventured on an independent explanation of the phenomena detailed, in keeping with my earlier work.

18. *Conclusion.*—A few general remarks may be added. Referred to a cubic kilometer the charges of the above nuclei would aggregate to about 200 coulombs, with an excess of negative charge as stated. If this region were spherical, with a superficial capacity, and if the charge of a given sign were transferred to the surface, its potential would be, in the average case, of the order of a thousand million volts. Finally the mobility of the nuclei is of the order of about eight-tenths of a mile in the unit electrostatic field, and the mere attrition of water by water is sufficient to generate them.

Brown University, Providence, R. I.

*Science, xvi, p. 633, 1902.

ART. X.—*The Morphogenesis of Platystrophia. A Study of the Evolution of a Paleozoic Brachiopod;* by EDGAR ROSCOE CUMINGS.

[Continued from p. 48.]

General Observations and Conclusions.

Platystrophia, as shown by its development and early history is descended from an ancestral *Orthis* having eight or nine plications on each valve, a ventral fold and dorsal sinus, and erect, high cardinal areas, with large open delthyria in each valve. Such a combination of characters is found in adult forms of the *Orthis lenticularis* group of the Upper Cambrian. The close resemblance of *Orthis lenticularis* to the nepionic shell of *Platystrophia*, together with its high variability and wide distribution, warrant the conclusion that it is the ancestor of the latter genus.

From this primitive stock was derived in the early Ordovician, a shell with a ventral sinus and dorsal fold; and with one plication in the sinus, two on the fold, and four to six on either side. In the early Trenton (or possibly before) this latter form underwent a differentiation into two species; one having fundamentally one plication in the median line of the sinus, representing the continuation of the median ventral fold of the nepionic stage, and an additional implanted plication on either side of this primary plication; the other having fundamentally two plications in the sinus arising by the bifurcation of the nepionic ventral fold. These species are *P. lynx* and *P. biforata*, respectively.

From *P. lynx* was derived in the Ordovician of America (*a*), by reduction of the secondary plications of fold and sinus, the variety *costata* of the lower Lorraine; (*b*), by elevation of the fold and extension of the cardinal angles, the variety *laticosta* of the Lorraine; and (*c*), by farther extension of the cardinal angles and addition of lateral plications, the species *acutilirata* of the Richmond; (*d*), by obsolescence of the secondary plications of fold and sinus in *laticosta*, was produced the form *unicostata* of the upper Lorraine. *P. lynx* attained its maximum development (acme), living in association with the above *varieties*, in the Lorraine of the Ohio Valley, and in the upper Lorraine passed through a series of gerontic modifications. A nearly normal form of *lynx* survived till the close of the Ordovician, making its appearance in great numbers in the extreme upper part (Madison beds) of that system. *P. acutilirata* passed through a series of retrogressive modifications in the upper Richmond, and became extinct at the close of the Ordovician. *P. costata*, by accentuation of the fold and sinus (bilobation), gave rise to the genus *Bilobites*, which survived till the early Devonian (Lower Helderberg).

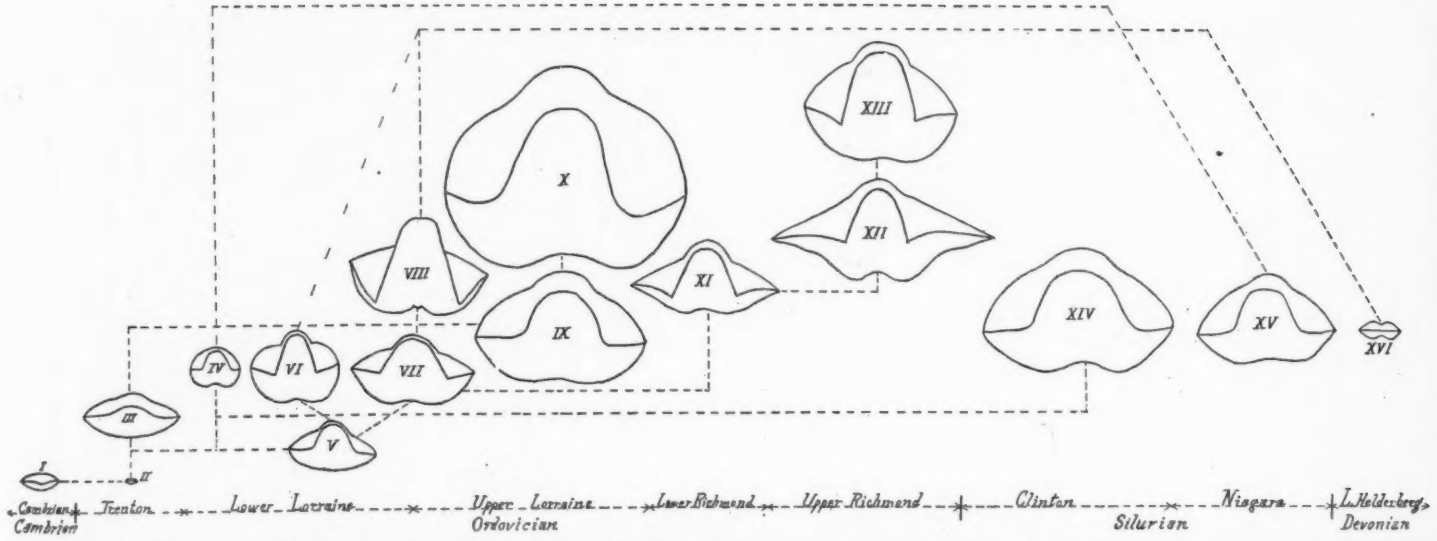


FIG. 26.—Diagram showing anterior views of the types of *Platystrophia* from the inception of the genus in the Trenton to its termination in the Niagara. I, *Orthis lenticularis* (corresponding to the nepionic *Platystrophia;* II, hypothetical early Ordovician representative of the group corresponding to the neanic growth stage of *Platystrophia;* III, normal Trenton *lynx* type; IV, *P. dentata*, derived from a primitive *biforata* type; V, lower Lorraine pauciplicate *lynx* type, from which were derived (VI) *P. costata* and (VII) *P. laticosta*, and from the later *P. unicostata* (VIII). From the Trenton *lynx* the Lorraine *lynx* (IX) descended directly and took on a gerontic modification (X) in the late Lorraine of the Ohio Valley. *P. laticosta* (VII) gave rise in early Richmond time to *P. acutilirata* (XI), and the latter, after becoming very *acuminate* (XII) in late Richmond time, assumed a regressive type (XIII). The Clinton form *P. biforata* (XIV) was derived in the early Ordovician of Europe from a primitive stock; and *P. dentata* of the Niagara (XV) represents the same stock as number IV. The latest member of the group, *Bilobites varicus* of the Lower Helderberg (XVI), was derived either from number VI or number VIII.

From the *biforata* stock were derived the Ordovician types *dentata* and *fissicostata*. Both *biforata* and *dentata* passed on into the Silurian, the former becoming extinct in the Clinton (in this country at least), and the latter in the Niagara, after assuming markedly primitive characters.*

The facts presented above are expressed diagrammatically on figs. 26 and 27. Fig. 26 shows anterior views of the forms of *Platystrophia*, characterizing the several geological divisions from the Cambrian to the Lower Devonian. One striking fact brought out by the diagram is the progressive increase in size (bulk) of the forms up to the culmination (acme) in the upper Lorraine; and the decrease in size from that point on. Another feature is the rapid multiplication of new forms in the Lorraine, and especially in the lower Lorraine. Another characteristic, which this diagram is especially designed to show, is the two types of sinus during the Ordovician: the angular (*VI, VII, VIII, XI, XII, XIII*), and the rounded (*III, IX, X, XIV*). These two types of sinus correspond to the two lines of descent, namely, from a pauciplicate and a multiplicate stock, respectively, as is shown in fig. 27. The Silurian forms find their nearest American Ordovician parallels, so far as this feature is concerned, in the *lynx* group. The European Ordovician forms, except *dentata*, are not shown on either fig. 26 or 27.

Fig. 27, in which the Roman numerals† correspond to those of fig. 26, is intended to express the ontogeny of each form as well as the phylogeny of the entire group. This figure shows several adult forms not shown in fig. 26. These are *Platystrophia lynx* of the upper Richmond (XVIII); *P. dentata* of the Niagara of the Mississippi Valley (XIX); *P. laticosta* of the lower Richmond (XI *a*); gerontic *P. costata* of the upper Lorraine (VI *a*); and *Bilobites verneuiliana* of the Clinton (Gotland). In this figure the forms below the horizontal lines, to which Arabic numerals are affixed, are ontogenetic stages of the forms above the horizontal lines, to which Roman numerals are affixed. It will be noted that the nepionic stage is the same for all except *Bilobites* (cf. 1–7 and 8–9). The neanic stage is the same for all the Ordovician forms (10–14), and has invariably one plication in the median line of

* There are several specific and varietal designations that have been applied to various forms of *Platystrophia*, which have not been mentioned above. These are *P. dorsata* Hisinger sp. (Leth. Suec., 1837, p. 76); and *P. tridens* and *P. terebratuliformis* McCoy sp. (Syn. Sil. Foss., Ireland, 1846, pp. 37, 38). Of *P. dorsata* deVerneuil says: "The *Atrypa dorsata* which we place in the synonomy of this species [*P. biforata*] has the plications more numerous, and might be considered as a variety of it." I have seen no specimens of this form, but probably deVerneuil's disposition of it is correct. *P. tridens* McCoy, as shown by his figures, is a typical *P. dentata*; and *P. terebratuliformis* is evidently a *P. fissicostata*, i. e., it belongs to the *biforata* group.

† Except *IV*, which is a pauciplicate *P. lynx*, the homœomorph of *P. dentata*.

the sinus and the beginning of another plication on either side (i. e., the type is fundamentally triplicate). The neanic stage of the Silurian forms (15, 16) has two plications in the sinus, arising by bifurcation of the median plication of the nepionic stage (i. e., the type is fundamentally biplicate). The early ephebic stages of upper Ordovician forms correspond closely to fully adult stages of lower and middle Ordovician forms (cf. 19 and 20 with III and IX; 22 with VI; 23, 24 and 25 with VII).

Distribution of Platystrophia.—On the map of the Northern Hemisphere (fig. 24) is shown the distribution of *Platystrophia.** Most of these localities have already been mentioned. Those which have been added through recent investigations may be mentioned briefly.

Platystrophia biforata (?) has been reported from Baffin Land by Schuchert.† The specimens are said to be small and narrow at the hinge. Whiteaves cites the same species from Akpatok Island, on the south side of Hudson Strait.‡

Recently *P. biforata* has been collected from the mainland near Nova Zembla (Khabarova) by the Swedish North Polar Expedition under Nansen.§ Johan Kiær, in a recent paper, reports *P. biforata* from near Christiania, Norway.‖ Weller reports *P. lynx* from New Jersey, from a horizon low in the Trenton.¶ White found the species in New Mexico at Silver City.** Professor H. S. Williams has a specimen of *P. lynx* from Arkansas.

It will be noticed that the genus has never been found in the Southern Hemisphere, nor in any region adjacent to the Pacific Ocean. Nevertheless the area of its known distribution represents nearly forty degrees of latitude and one hundred and seventy degrees of longitude.

We should not be too hasty in drawing conclusions from the above facts of distribution, in regard to questions of correlation and Paleozoic geography; nevertheless several points seem to me, if not demonstrated, at least forcibly suggested.

The biplicate type of *Platystrophia*, so characteristic of the European Ordovician, is absolutely wanting in the American Ordovician outside of the Hudson-Champlain trough. This

* This map is based on a stereographic projection upon the plane of the Equator, prepared by Professor S. L. Penfield. (See this Journal, vol. xiii, May, 1902, p. 252.) The amount of distortion within the 40° of latitude is slight.

† Proc. U. S. National Museum, xxii, 1900, pp. 151, 158.

‡ This Journal (4), vii, 1899, pp. 433, 434.

§ Johan Kiær, Sci. Res. N. Polar Expd., vol. iv, xii, 1902, p. 7.

‖ Separataftryk af Norges Geologiske Undersogelses Aarbog for 1902, p. 61

¶ Kümmel and Weller, Bull. Geol. Soc. Amer., 12, 1901, p. 158.

** Geol. Expl. West of the 100th Meridian, 1874, iv, p. 74.

indicates, as pointed out by Ulrich and Schuchert,* a connection of this latter area with Europe during the early Ordovician, and its separation from the Mississippi area. I believe also that the strong similarity of *P. biforata* of the Champlain trough to the European lower Ordovician forms indicates close contemporaneity of the two terranes.

Again, the Clinton *Platystrophia* of this country is almost identical with the European *P. biforata*, and therefore indicates a migration of European forms into American waters of the Mississippi area at the close of the Ordovician. This also coincides with the views of the authors just mentioned. The Niagara species, *P. dentata*, is identical with the Gotland form, and differs from the Clinton form, thus indicating a second migration of European forms during Niagara time. The bearing of this evidence upon Dr. Weller's views has been pointed out in another place.

A point perhaps worth calling attention to, is the erroneous ideas current in regard to the distances to be covered by these migrating forms and the routes pursued, that we obtain from Mercator projections and globular and stereographic projections on any plane but that of the Equator. By reference to the map, fig. 24, it is clear that the route of a form migrating from Gotland, for example, into the Mississippi Valley, is no more circuitous by way of Hudson Bay than by way of the Atlantic. It is even less so.

Laws of the Evolution of Platystrophia.—It is not to be assumed that the history of *Platystrophia* outlined in the preceding pages is in any way complete, or that it could ever be made complete by any amount of research. Every worker in this department of science is painfully aware, when he appeals to the original sources of information, the rock-strata, of the many volumes of the record irretrievably lost, and of the many events never recorded at all. My aim has been to have before me specimens of all the forms of *Platystrophia* known from American terranes; and this has been rendered possible through the kindness of the gentlemen mentioned above, to whom I once more express my gratitude. I should have been glad, indeed, to have had the same opportunity of examining all the European forms; but for the present this is impracticable. Imperfect access to available material is, therefore, added to the imperfections of the original sources of information. What, therefore, rests on theory the reviewer must accept or reject according to his convictions of its merits or demerits. The facts, many of which I have had the pleasure of ascertaining and many of which are due to the labors of others, I have endeavored to present in such a way that the risk of confusing them with theory will be avoided.

* Bull. N. Y. State Mus., No. 52, 1902, pp. 633–663.

The observations which follow assume that the history of *Platystrophia*, outlined above, is in the main correct; and have suggested themselves from time to time as the investigation proceeded.

Variability.—Platystrophia presents its highest degree of variability near the beginning (epacme) of its history, and thenceforward becomes progressively less variable, till finally only characters of no physiological importance are affected. In other words, *variability is progressively restricted to characters of lower and lower taxonomic value.**

Considering the entire group, the presence of a ventral sinus is a generic character from the early Ordovician on; but the ancestral form, *Orthis lenticularis*, has the sinus in the *dorsal* valve (as in the nepionic shell of *Platystrophia*), so that at some time between the Cambrian and Trenton the type varied in this respect. Since, moreover, the fold and sinus of Brachiopods are undoubtedly due to the presence and position of the brachia, such a transfer of the sinus from one valve to the other indicates a considerable readjustment of the internal organs, and of the brachia in particular.

In all forms of *Platystrophia* above the basal Trenton, the sinus is either definitely biplicate or definitely triplicate; and this character delimits the primitive species *biforata* and *lynx*. In the early Trenton, however, we meet with both biplicate and triplicate shells associated together, and the inference is that at that time the mode of origin of the plications of the fold and sinus was variable. In the lower Lorraine the pauciplicate *P. lynx* has indifferently one, two, or three plications in the sinus; but a little later these peculiarities tend to become fixed in distinct types, so that ultimately *laticosta*, and especially its derivative *acutilirata*, have almost constantly three plications in the sinus, while *Bilobites* derived from *costata* has the single median plication of the latter fixed as a persistent nepionic character which is absolutely invariable. Throughout the Trenton and Lorraine *P. lynx* varies extensively in contour and number of plications, the limits being between six and twelve plications on each side of the fold and sinus, and the average seven on each side. In the late Richmond, where *lynx* reappears in great numbers, it has almost constantly between nine and twelve plications on each side of the fold and sinus, and the shell index is uniformly high. The sinus index, which seems to have no fixity at all in Lorraine forms, is in *acutilirata* fairly constant. The early forms of the *P. biforata* group, according to European authors, vary extensively in contour and number of plications, and this variability is still high, especially the number of plications, in our Clinton forms; but

* Cf. Hyatt, Proc. Bos. Soc. Nat. Hist., xxxii, 1895, p. 371.

the *P. dentata* of the Niagara is almost absolutely invariable in these respects.*

A corollary of the law of progressive restriction of variability is the *rapid production of new types near the beginning (during the epacme) of a phylum.*† Thus the two primitive species *biforata* and *lynx* were produced in the early Ordovician; *laticosta*, *costata*, and *dentata*, in the Trenton-Lorraine; *unicostata* in the upper Lorraine, and *acutilirata* in the Richmond. The entire Silurian furnishes not a single additional type. *Bilobites*, the only genus derived from *Platystrophia*, originated some time during the Ordovician. *The notion that species are formed by very gradual increment of selected variations certainly does not suit the present case.* Many of the earliest individuals of *P. lynx* and *P. biforata* are as typical of those species as any that occur subsequently. So many early specimens of *P. laticosta* and *P. costata* are typical representatives of their respective lines. *The fundamental difference between the early and later history of these types is the presence of intermediate groups during the former period and their absence during the latter.*‡

It is possible that species may originate within a single generation. This is even insisted on by De Vries.§ It certainly has occurred among domestic races, as Darwin‖ himself points out, though systematists seem loth to admit that anything is a species the origin of which is a matter of historical record! Cope¶ has suggested the sudden origin of genera through the law of acceleration. Bailey,** in a very suggestive chapter on experimental evolution, shows that many species of plants originate suddenly under cultivation. I do not wish to be understood as maintaining that species habitually originate after this fashion; but cases such as that of *Platystrophia* (and many similar ones will occur to the mind of every paleon-

* Shaler's name, *regularis*, applied to the Anticosti form of this species, probably alludes to this fact of invariability.

† On this subject see Hyatt, Proc. Bos. Soc. Nat. Hist., xxxii, p. 371.—Williams, Geological Biology, pp. 321, 322.—The fact has been noted by many other paleontologists: Schuchert, Beecher, Hall, Clarke, Walcott, Gratacap, etc.

‡ Prof. H. S. Williams has shown that the Silurian-Devonian type *Atrypa reticularis* affords a remarkable illustration of this law. (Geological Biology, pp. 315–322.) The Devonian *Spirifers*, on the other hand, seem to be a group in which segregation of species was more rapid, although *S. mucronatus* and *S. disjunctus* (Gosselet, Extrait des Mem. de la Soc. Géol. du Nord, iv, i, 1894) were certainly protean. A comparison of Hall's plates of *Spirifer* (Pal. N. Y., vol. iv) with our fig. 27 shows that the latter presents material enough for a dozen species, but for the connecting forms.

§ Origin of species by mutation, Science, N. S., xv, No. 384, May, 1902.

‖ Animals and Plants under Domestication, 1868.

¶ Origin of the Fittest, 1886, p. 79.

** Survival of the Unlike, 1896, pp. 107–137.

tologist) certainly point to the conclusion that *given a new and vigorous stock in a favorable environment, the initiation of new species takes place with great rapidity.* It does not matter whether the new stock has been derived by migration from some outside region or as an offshoot of an endemic stock, so long as its physiological peculiarities, or physical isolation, remove it sufficiently from competition with other stocks.*

After the initiation of new types, their segregation from each other into definite groups (species) was relatively slow. Intermediate forms persisted for some time. Segregation was not accomplished until most of the characters of the types had become fixed.

Intrinsic evolution.—Certain phenomena of the evolution of *Platystrophia* find their explanation in the progressive development or accentuation of characters of high physiological importance along the same line in different members of the genus, especially during its epacme. These are the phenomena of *morphological equivalence*† and *homœomorphy*,‡ of both of which *Platystrophia* affords excellent examples.

By morphological equivalence is meant the occurrence of similar forms in similar succession under like conditions of environment; and by homœomorphy, similarity of species in general features with dissimilarity in details. *P. lynx* and *P. biforata* present examples of both. These two species are perfectly distinct; nevertheless, the fact that the early representatives of *P. lynx* in this country have been persistently referred to *P. biforata*, while the later Russian Ordovician representatives of *P. biforata* have been as persistently referred to *P. lynx*, is good evidence of the parallelism of the two; and the similarity of the sediments in which they occur and of the faunas with which they are associated, is evidence of the similarity of environmental conditions. Both species run through a similar series of changes. Since they were derived from the same radical they were of course alike at the outset. In the middle Ordovician of Russia (see fig. 6 ante) we have a form which in size, gibbosity, incurvature of the beaks, number of plications, shell index, and cardinal angle is the homœ-

* Thus *Platystrophia* was a highly anomalous type of Orthid, a fact which gave it a distinct advantage. A factor that may have played an important part in the rapid evolution of new types, since it furnishes precisely the favorable conditions of physical environment demanded, has been pointed out by Prof. T. C. Chamberlin (Jour. Geol., vi. 1898, pp. 600–604). This is the extension of submarine shelves and epicontinental seas during periods of base-leveling and transgression. Such conditions existed, according to Chamberlin, in the middle Ordovician, the very time when *Platystrophia* attained its greatest expansion. See also Beecher, this Journal, vi, 1898, pp. 132, 133.

† Hyatt, Genesis of the Arietidæ, Mem. Mus. Comp. Zool., xvi, No. 3, 1889, p. viii.

‡ Buckman, Homœomorphy among Jurassic Brachiopoda, Proc. Cotteswold Nat. Field Club, xiii, 4, 1901, pp. 231, *et seq.*

omorph of *P. lynx* of the upper Lorraine of this country: *but it is specifically distinct.* Again in the upper Richmond of this country is a form of *P. lynx* similar in almost every respect to *P. biforata* of the upper Ordovician and Clinton; *yet again specifically distinct.* The parallelism of the two series *lynx* and *biforata* is complete. Examples of homœomorphy besides those just mentioned, are *P. dentata* and *P. lynx pauciplicata*, biplicate form,—almost precisely alike in the adult, but differing in the early stages (neanic): *P. costata* and *P. laticosta unicostata*,—alike in number of plications and plication of the fold and sinus but differing slightly in cardinal angle, depth of sinus, and shell index, and very differently derived: the gerontic *P. acutilirata* and the upper Richmond *P. lynx*, differing only in early ephebic stages.

The relations of these homœomorphic forms are indeed suggestive. The feature that infallibly distinguishes the *P. lynx* and *P. biforata* groups is the mode of origin of the plications of the sinus and fold. Aside from this one character, however, the evolution of the two groups seems to have been determined by the same set of intrinsic characters which responded to the two sets of environmental conditions by similar reactions. These intrinsic characters centered in the progressively increasing development of the brachia. It was stated above that the shifting of the sinus from the dorsal valve (in *Orthis lenticularis*) to the ventral valve (in *Platystrophia*) was due to the increasing development of the brachia. The grounds for this statement are, the plan of symmetry of the shell which is undoubtedly primarily determined by the brachia, and the pretty general restriction of the sinus to the ventral valve. In those brachiopods (*Spiriferacea*, *Terebratulacea**) in which the extent of the brachia is definitely indicated by their calcified supports, the connection between the brachia and the sinus is obvious enough, and the development of the sinus is usually directly related to the extent and position of the brachia. In inarticulate brachiopods (*Atremata*, *Neotremata*) where there is more freedom of motion of the valves upon each other, a fold and sinus are seldom developed, for obvious reasons.

As there are no representatives of the *Orthidæ* extant, the condition of the brachia in that group can only be inferred

* In the *Terebratulacea* the sinus is more often in the dorsal valve than is the case in any other group. A glance at the brachia of such a shell will show that this is in reality the exception that proves the rule, for here the median lobe of the brachia extends toward the ventral mantle so that the real hiatus between the right and left lobes of the brachia comes on the side toward the brachial valve. This is beautifully shown in the figure of *Terebratulina coreanica* (fig. 13, plate 46) in Morse's recent splendid memoir on living brachiopods (Mem. Bos. Soc. Nat. Hist., v, 1902). Compare with *Spirifer striatus*, fig. 576 A, Zittel's Text book of Paleontology (Eastman Tr.), p. 336.

from indirect evidence.* *Davidsonia* of the Devonian has strongly impressed spiral markings in the interior of the ventral valve, indicating coiled brachia of several turns. In *Leptæna* similar evidence indicates still fewer turns to the brachia.† *Rafinesquina Jukesi*‡ shows similar impressions of one or two whorls in the spires. Quite similar impressions are sometimes seen in *Productus*.§ Among the *Orthidæ* there is no such direct evidence of the position and extent of the brachia; but it cannot be supposed that they differed materially in the *Strophomenidæ* and primitive *Orthidæ*. In both cases the brachia consisted of low spires of few turns with their axes approximately at right angles to the plane of separation of the valves. In *Platystrophia*, on the other hand, the strong tendency toward a profound sinus, together with the great extension of the cardinal angles, and general large size and robustness of the shell, indicate that the brachia were well developed and that probably the axes of the spires lay in the transverse diameter of the shell. The striking difference between *Platystrophia* and all the other *Orthidæ* may very well have been due primarily to this peculiarity. If the modifications of the sinus are correlated with modifications of the brachia, this view is certainly well founded, for the main lines of evolution of this genus are as a matter of fact marked out by modifications affecting the sinus.‖ If, further, the modification of the brachia was progressive and affected the entire genus, we have a perfectly adequate reason for the parallel evolution of the *lynæ* and *biforata* groups, and an explanation of the homœomorphic forms mentioned above. Thus a wide separation of the two lobes of the brachia would account for the profound sinus and obsolescence of the lateral plications of the sinus in *P. costata* and *P. laticosta unicostata* and for the ultimate bilobation of the shell in *Bilobites*. The force of this will be seen at once if we compare such a form as *Spirifer mucronatus* (which *Platystrophia* so closely resembles) in which the sinus is deep, with *Meristina* in which it is shallow or lacking. In the former the bases of the spires are widely

* *Thecidium*, the only survivor of the *Strophomenacea*, has a rather feeble development of the brachia. Since, however, we are led to believe that this is a degenerate type, no safe conclusions in regard to the morphology of the brachia of ancient *Strophomenacea* can be based upon it.

† Davidson, Sil. Brachiopoda, 1869, pl. xxxix, fig. 16.

‡ Ibid. pl. xxxvii, figs. 25, 26.

§ *P. giganteus*, Zittel, Textbook of Paleontology (Eastman Tr.), p. 318, fig. 532 B.

‖ It may, of course, be argued that external factors caused changes in the depth of the sinus and that these changes caused readjustments of the brachia. This is gratuitous assumption. There is absolutely no reason why the mantle of a Brachiopod should sag in this particular region except that at this point it lacks the support of any internal structure. The development of a sinus under such conditions is a mechanical necessity.

separated; in the latter they are closely approximated. In the same way we may compare *Pentagonia* and *Meristella*.

The extent of the brachia may also bear some definite relation to the width of the shell.* Thus it might be reasonably expected that in such a form as *P. acutilirata* the spires would have a greater number of volutions than in such a form as *P. costata*. The analogy of the *Spirifers* holds here also; for in *S. mucronatus* there are often just as many turns to the spirals as plications on the shell. The *Spiriferacea* indeed suggest that there may be a more or less definite correlation between the presence and number of plications and the extent and position of the spires of the brachia.

The subject of the cause of plications is an exceedingly tempting one, but leads too far afield into the realm of theory to warrant extended discussion here. A few suggestions may nevertheless be hazarded.

The relation of the brachia to the mantle in structure and function is intimate, since the former are derived from the latter, and both coöperate in the function of respiration.† Some definite relation between the volumes of the two is, therefore, to be expected. Increase in the extent of the brachia is accomplished by folding and coiling of various sorts, while increase in mantle area is accomplished by radial growth (increase in the absolute size of the shell) and much more effectively by plication. The coöperative efficiency of the brachia and mantle can, therefore, for a shell of given size, be greatly increased by coiling or folding of the brachia and plication of the mantle. The correlation may be even more precise: for where the axes of the spires lie in the transverse diameter of the shell the position and direction of the successive volutions is such that the mantle may conform to them in shape, folding up and down as it crosses each turn.

There are other factors that may have been concerned in causing or accentuating shell plication. The greatly increased length of the mantle border of a plicated shell as compared with a smooth shell of the same size, is obvious. Such a plicated shell could admit the respiratory and food-bearing currents of water, and at the same time keep out foreign particles and disagreeable visitors, because the greatly lengthened slit between the mantle margins would not necessitate so wide a gaping of the valves of the shell. That there actually is a correlation between the gape of the valves and the presence of

* Beecher has pointed out the effect of mechanical restraint in the production of transverse shells (this Journal, vi, 1898, p. 337). Doubtless this factor was concerned in the great extension of the cardinal angles of *P. acutilirata*.

† The brachia are not directly respiratory organs, but indirectly, by causing the flow of currents of water over the mantle.

plications is suggested by the fact that most shells with long hinge-lines and high areas, or any other conformation of the shell indicating a short pedicle, close appression to the surface of support, and consequent interference with the mobility of the valves, are plicate. This is notably true of the *Spiriferacea* and *Terebratulacea*. On the other hand, most shells with prominent ventral beak and apical foramen (many *Athyridæ* and *Terebratulidæ*), a conformation indicating great freedom of movement of the valves, are non-plicate. Among Atremata and Neotremata, where there is often very great mobility of the valves, plications are lacking; and as has been recently pointed out by Morse* the setæ are here well developed and serve the purpose of strainers. In articulate brachiopods the setæ are usually small or aborted. A possibly analogous correlation is seen in the Pelecypoda between the development of plications and siphons. When the siphons are well developed and control the incurrent and excurrent water, the shell is seldom plicate. On the other hand, many of the shells which lack siphons are strongly plicate (*Pectinacea*, *Ostracea*, *Pteriacea*, *Arcacea*, *etc.*).† There is in both brachiopods and pelecypods a tendency to improvise tubes for the passage of incurrent and excurrent water by throwing the margins of the mantle into folds or wrinkles. Morse (*loc.cit.*) has pointed this out in the case of *Lingula lepidula*, and N. Yatsu‡ in that of *L. anatina*. Some fossil shells suggest the same thing (*Pentamerus*, *Leptæna*).§ Prof. R. T. Jackson informs me that the same is true of some asiphonate Pelecypoda. This tendency may have had something to do in both classes with the initiation of plications. There is undoubtedly also a relation between habitat and plication. It is well known that oysters grow smooth or plicate according to the nature of the bottom and purity of the water. Woodward‖ has pointed out an analogous relation between shell ornamentation and habitat among the Brachiopoda. Prof. H. S. Williams¶ believes that plications in the Brachiopoda are due to accelerated peripheral growth of the mantle. This is rather a restatement of fact than an explanation of it. In some brachiopods the plications of the nepionic shell correspond accurately with the setæ.** The prolongations of

* Mem. Bos. Soc. Nat. Hist., v, No. 8, 1902.

† I am aware of the fact that even in asiphonate Pelecypods, water is not necessarily admitted along the whole margin of the mantle but is more or less confined to definite parts of it. See Rémy Perrier, Éléments d'Anatomie Comparée, p. 661.

‡ On the habits of Japanese *Lingula*, Annotationes Zool. Jap. iv, pt. 2, 1902, pp. 63, 64.

§ Davidson, Sil. Brachiopoda, 1869, pl. xxxix, fig. 4.

‖ Quoted by Œhlert in Fischer's Manuel de Conchyliologie, p. 1243.

¶ Geol. Biol., p. 309.

** See Morse, Mem. Bos. Soc. Nat. Hist., ii. pt. i, No. 2, 1871, pl. 1, fig. 26.

these nepionic plications would account for shell plication in some instances; and probably striæ are usually due to the presence of setæ and other organs in the mantle margins.

Progressive and retrogressive evolution.—The greater part of the history of *Platystrophia* is progressive. There may indeed have been retrogression in minor details accompanying general progressive evolution; as in the obsolescence of the secondary plications of the sinus of *P. laticosta* and *P. costata.* There was a return in this particular to a primitive condition. In the later history of the group genuinely retrogressive series are met with, notably *P. acutilirata* (upper Richmond form) and *Bilobites varicus.* *P. lynx* of the upper Lorraine, we have seen, presents markedly gerontic characters but scarcely gives rise to a truly retrogressive series. General retrogression, in the *Platystrophia* group, in every case heralds extinction. Characters added at various times during the history of the genus are lost in the inverse order of their acquisition. For example, in *P. acutilirata* the latest added character is the acuminate cardinal angles. This is the first feature to disappear in retrogression. In extreme retrogression the sinus decreases in depth and angularity, the auriculation of the cardinal extremities disappears, and the shell assumes a markedly *lynx*-like aspect. *Bilobites varicus*, as pointed out by Beecher,* first loses the pronounced bilobation that characterizes *B. verneuilianus.* It never loses the vestigial median plication of the ventral sinus. The older a character, the more persistent it is.

In all these cases of retrogression the process seems to be due to the acceleration of gerontic modifications. This is especially well shown in *P. acutilirata*, where we first meet with an occasional gerontic individual which has lost its acuminate cardinal angles and finally in higher zones find the whole group thus affected, and the gerontic modifications appearing in early ephebic stages. I have noticed a precisely parallel case in *Spirifer mucronatus* of the Devonian. Some of the later forms of this species are so modified by the acceleration of gerontic characters that the cardinal angles approximate 90°, the more acuminate stages being indicated by the growth lines on the posterior portion of the shell. The inverse order of disappearance of characters applies here, also, as it seems to in practically all retrogressive types.†

Yale University Museum, New Haven, Conn., Nov., 1902.

* This Journal, (3), xlii, 1891, p. 56.

†For other examples of retrogression, see the various papers of Beecher and Beecher and Clarke on the development of the Brachiopoda, and Beecher's chapter on the Trilobita in Eastman's translation of Zittel's Grundzüge. See also Hyatt's numerous papers on the Cephalopoda, and Jackson's memoir on the Phylogeny of the Pelecypoda, Mem. Bos. Soc. Nat. Hist., iv, 1890.

REFERENCES.

ATWATER, C.—On some ancient Human Bones, etc., with a notice of the Bones of the Mastodon or Mammoth and of various Shells found in Ohio and the West. Am. Jour. Sci. (1), ii, 1820.

BAILEY, L. H.—Survival of the Unlike, 1896.

BEECHER, C. E.—Development of the Brachiopoda, pt. ii. Am. Jour. Sci., (3), xliv, 1892.

——Development of Bilobites. Am. Jour. Sci. (3), xlii, 1891.

——Origin and Significance of Spines. A Study in Evolution. Am. Jour. Sci. (4), vi, 1898.

——and CLARKE, J. M.—The Development of some Silurian Brachiopoda. Mem. N. Y. State Mus., i, 1889.

BILLINGS, E.—Geology of Canada, 1863.

BUCH, L. VON.—Essai d'une Classification et d'une Description des Delthyris, etc. Mem. Soc. Géol. de France, iv, 1840.

BUCKMAN, S. S.—The Bajocian of the Sherborne District, etc. Quar. Jour. Geol. Soc. Lond., xlix, 1893.

——Homœomorphy among Jurassic Brachiopoda. Proc. Cotteswold Nat. Field Club, xiii. pt. 4,1901.

CHAMBERLIN, T. C.—A Systematic Source of Evolution of Provincial Faunas. Jour. Geol., vi, 1898.

CONRAD, T. A.—Observations on the Silurian and Devonian Systems of the United States, with Description of new Organic Remains, etc. Jour. Acad. Nat. Sci., Philadelphia, vol. viii, 1842.

COOK, O. F.—Four Categories of Species. Am. Nat., xxxiii, 1899.

COPE, E. D.—Origin of the Fittest, 1886.

CUMINGS, E. R., and MAUCK, A. V.—A Quantitative Study of Variation in the Fossil Brachiopod Platystrophia lynx. Am. Jour. Sci. (4), xiv, 1902.

DANA, J. D.—Manual of Geology, Fourth Edition, 1894.

DARWIN, C. R.—Variation of Animals and Plants under Domestication, 1868.

DAVIDSON, T.—Silurian Brachiopoda. Paleontographical Society, 1869–'71.

DENNIS, D. W.—Two cases of Variation of Species [of Brachiopoda] with horizon. Proc. Indiana Acad. Sci., 1898.

EICHWALD, E.—Skizze von Podolien, 1830.

FISCHER, P.—Manuel de Conchyliologie, 1880–'87.

FOERSTE, A.—The Clinton Group of Ohio. Bull. Dennison University [Granville, Ohio], i, 1885.

FRECH, F.—Lethæa Paleozoica, 1897.

GOSSELET, J.—Études sur les Variations du Spirifer Verneuili. Extrait des Mem. de la Soc. Géol. du Nord, tome iv, i, 1894.

HALL, J.—Geology of New York, Report on Fourth District, 1843.

—— Paleontology of New York, i, 1847.

—— ——— ——— iv, 1867.

—— and CLARKE, J. M.—Paleontology of New York, viii, pts. i and ii, Brachiopoda, 1892.

HISINGER, W. VON.—Lethæa Suecica, 1837.

HYATT, A.—Bioplastology and the Related Branches of Biologic Research. Proc. Bos. Soc. Nat. Hist., xxvi, 1893.

—— Genesis of the Arietidæ. Mem. Mus. Comp. Zool., xvi, 3, 1889.

—— Genesis of the Tertiary Species of Planorbis at Steinheim. Anniversary Mem. Bos. Soc. Nat. Hist., 1880.

—— Phylogeny of an Acquired Characteristic. Proc. Am. Philos. Soc., xxxii, 1895.

JACKSON, R. T.—Phylogeny of the Pelecypoda, the Aviculidæ and their Allies. Mem. Bos. Soc. Nat. Hist., iv, 1890.

JAMES, U. P.—Description of new species of Brachiopoda from the Lower Silurian Rocks—Cincinnati Group. Cincinnati Quar. Jour. Sci., i, 1874.

JAMES, U. P.—Catalogue of the Lower Silurian Fossils of the Cincinnati Group, 1871.
KAYSER, E.—Lehrbuch der Geologie, 1891.
KEYES, C. R.—Geology of Missouri, vol. v, Paleontology, 1894.
KIÆR, J.—Studier over den Norske Mellemsilur. Separataftryk af Norges Geologiske Undersogelses Aarbog for 1902.
—— The Lower Silurian at Khabarova. Scientific Results of the Norwegian North Polar Expedition, 1902.
KÜMMEL, H. B., and WELLER, S.—Paleozoic Limestones of the Kittatinny Valley, New Jersey. Bull. Geol. Soc. Amer., 12, 1901.
LAMANSKY, WL.—Neue Beiträge zur Vergleichung des Ostbaltischen und Skandinavischen Untersilurs. Centralblatt f. Min. Geol. u. Pal. (Neues Jahrb.), No. 20, 1901.
LAPPARENT, A. DE.—Traité de Géologie, 1900.
LINDSTRÖM, G.—Bidrag till Kännedomen om Gotlands Brachiopoder. Öf. Sven. Vetens. Akad., xvii, 1860.
—— Ueber die Schichtenfolge des Silur auf Insel Gotlands. Neues Jahrb. f. Min. Geol. u. Pal., 1888, i.
MATTHEW, G. F.—Illustrations of the Fauna of the St. John Group, No. vi. Trans. Roy. Soc Canada, ix, Sec. iv, 1891.
McCOY, F.—British Paleozoic Fossils, 1852.
—— Synopsis of the Silurian Fossils of Ireland, 1846.
MEEK, F. B.—Paleontology of Ohio, i, 1873.
MILLER, S. A.—Monograph of the Class Brachiopoda of the Cincinnati Group. Cin. Quar. Jour. Sci., ii, 1875.
MORSE, E. S.—Early Stages of Terebratulina Septentrionalis. Mem. Bos. Soc. Nat. Hist., ii, pt. i, No. 1, 1871.
—— Observations on Living Brachiopoda. Mem. Bos. Soc. Nat. Hist., v, No. 8, 1902.
NETTLEROTH, H.—Kentucky Fossil Shells. A Monograph of the Fossil Shells of the Silurian and Devonian Rocks of Kentucky, 1889.
NEUMAYER, M.—Erdgeschichte, 1895.
NICKLES, J. M.—Geology of Cincinnati. Jour. Cincinnati Soc. Nat. Hist., xx, No. 2, 1902.
PANDER, C. H.—Beiträge zur Geognosie des russischen Reiches, 1830.
PENFIELD, S. L.—On the Use of the Stereographic Projection for Geographical Maps and Sailing Charts. Am. Jour. Sci. (4), xiii, 1902.
PERRIER, R.—Éléments d' Anatomie Comparée, 1892.
RAYMOND, P. E.—The Crown Point [N. Y.] Section. Bull. Am. Paleontology, No. 14, 1902.
RUEDEMANN, R.—Evidence of Current Action in the Ordovician of New York. Am. Geol., xix, 1897.
—— Hudson River Beds near Albany [N. Y.] and their Taxonomic Equivalents. Bull. N. Y. State Mus., vol. 8, No. 42, 1901.
—— The Trenton Conglomerate of Rysedorph Hill, Rensselaer Co., N. Y., and its Fauna. Bull. N. Y. State Mus., No. 49, 1901.
SARDESON, F. W.—The Galena and Maquoketa Series. On Orthis testudinaria. Am. Geol., xix, 1897.
SCHLOTHEIM, E. F. VON.—Die Petrefactenkunde auf ihrem jetsigen Standpunkte, 1820.
SCHMIDT, F.—Beitrag zur Geologie der Insel Gotland. Archiv. f. d. Naturkunde Liv.-Ehst.-und Kurlands, Ser. i, Bd. ii, Lief. ii, 1859.
—— On the Silurian (and Cambrian) Strata of the Baltic Province of Russia as Compared with those of Scandinavia and the British Isles. Quar. Jour. Geol. Soc. Lond., xxxviii, 1882.
—— Untersuchung über die Silurische Formation von Ehstland Nord-Livland und Oesel. Archiv. f. d. Naturkunde Liv.- Ehst.- und Kurlands, Ser. i, Bd. i, 1858.
SCHUCHERT, C.—On the Lower Silurian (Trenton) Fauna of Baffin Land. Proc. U. S. National Museum, xxii, 1900.

SCHUCHERT, C.—Synopsis of American Fossil Brachiopoda including Bibliography and Synonomy. Bull. U. S. Geol. Surv., No. 87, 1897.

SHALER, N. S.—Brachiopoda of the Ohio Valley, 1887.

—— Bull. Mus. Comp. Zool., 4, 1865, p. 67.

SOWERBY, J. DE C.—In Article on the Classification of the older Stratfied Rocks of Devonshire and Cornwall, by Sir R. I. Murchison and Adam Sedgwick. Trans. Geol. Soc. Lond., 2d Ser., vol. v, 1840.

ULRICH, E. O., and SCHUCHERT, C.—Paleozoic Seas and Barriers in Eastern North America. Bull. N. Y. State Mus., No. 52, 1901.

VERNEUIL, E. DE.—Géol. de la Russie d'Europe et de Montagnes de l'Oural, 1845.

VRIES, H. DE.—The Origin of Species by Mutation. Science, N. S., xv, No. 384, 1902.

WALCOTT, C. D.—The Fauna of the Lower Cambrian or Olenellus Zone. 10th Ann. Rep. U. S. Geol. Surv., 1891.

WELLER, S.—The Silurian Fauna interpreted on the Epicontinental Basis. Jour. Geol., vi, 1898.

WHITEAVES, J. F.—Recent Discovery of Rocks of the Age of the Trenton Formation at Akpatok Island, Ungava Bay, Ungava. Am. Jour. Sci. (4), viii, 1899.

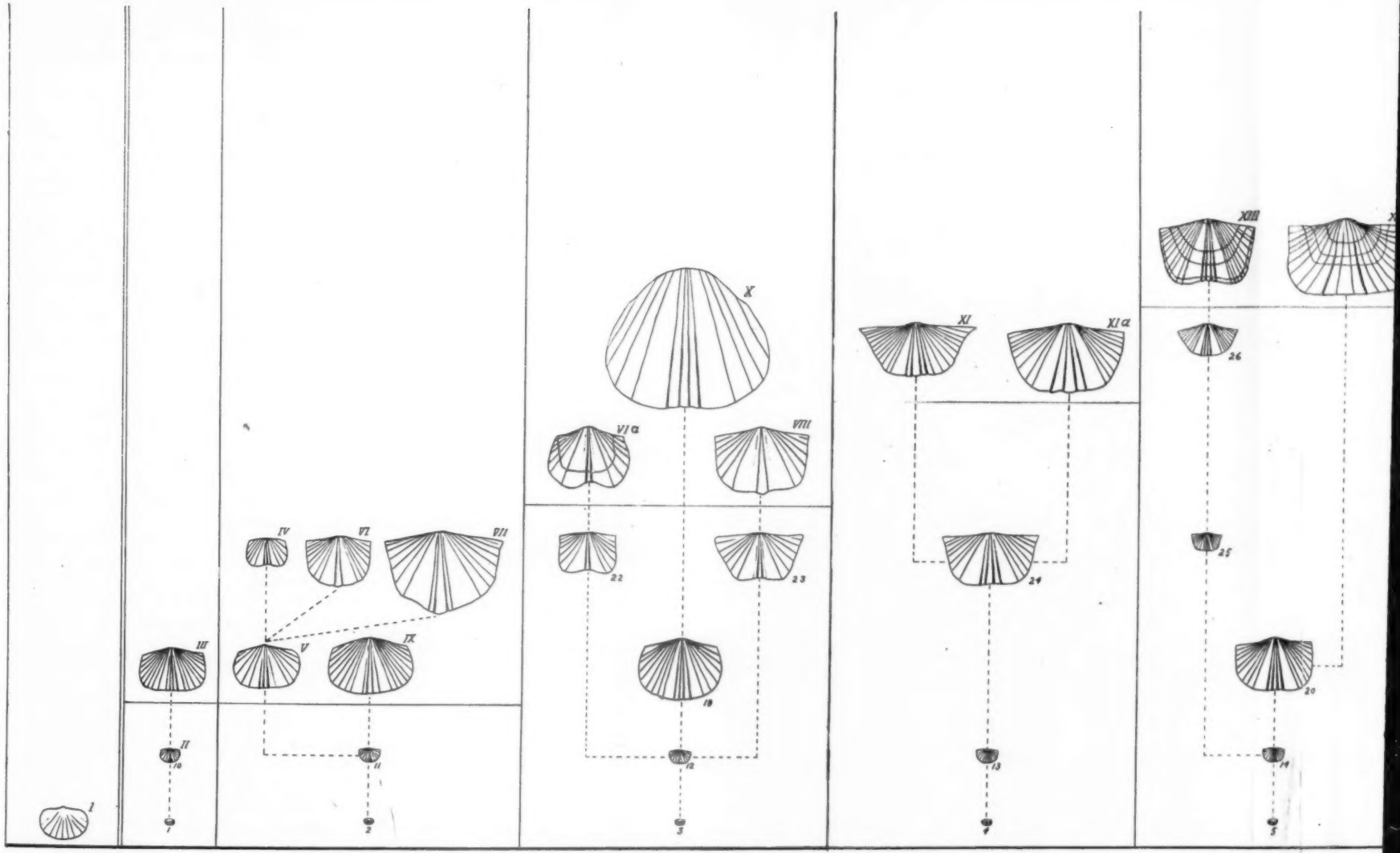
WILLIAMS, H. S.—Geological Biology, 1895.

WINCHELL, N. H. and SCHUCHERT, C.—Geology of Minnesota, vol. iii, pt. i, Paleontology, 1892.

WYSOGORSKI, J.—Zur Entwicklungsgeschichte der Brachiopodenfamilie der Orthiden im ostbaltischen Silur. Zeitschr. d. Deutch. Geol. Ges. Jahrg., 1900.

YATSU, N.—On the Habits of Japanese Lingula. Annotationes Zool. Jap., iv, pt. 2, 1902.

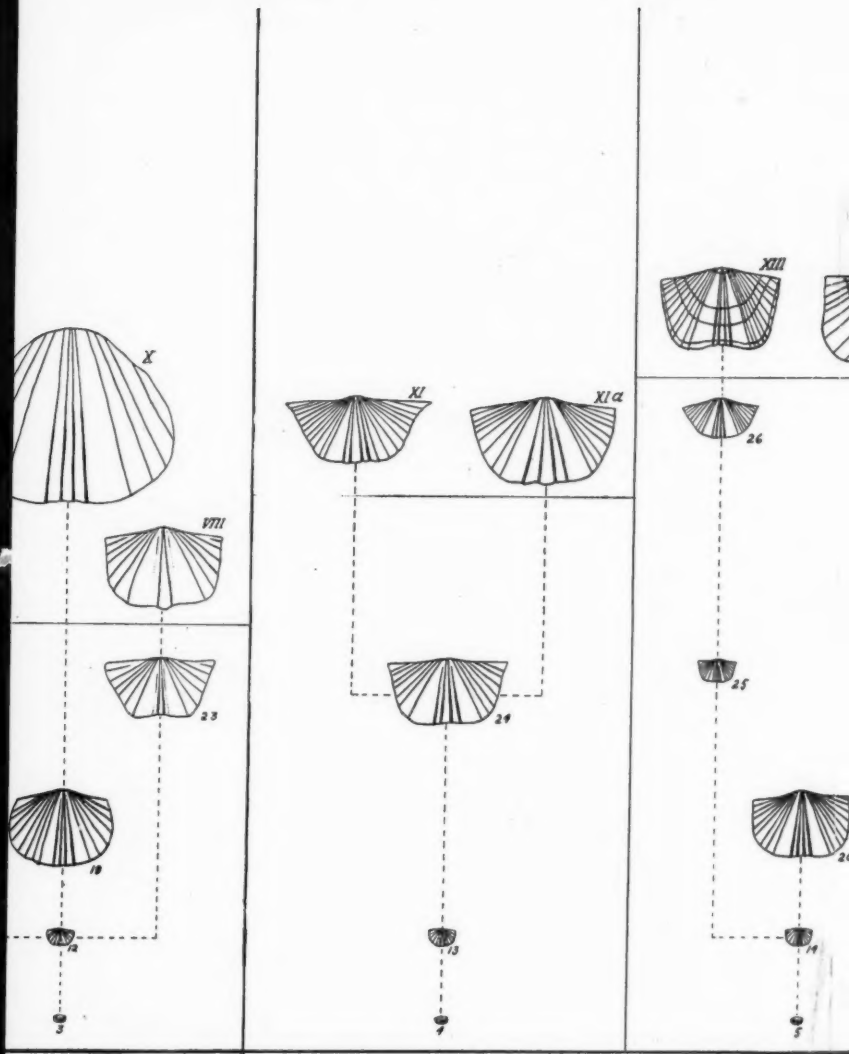
ZITTEL, K. A. VON.—Textbook of Paleontology (Eastman Tr.), 1899.



Upper Cambrian. | *Trenton.* | *Lower Lorraine.* | *Upper Lorraine.* | *Lower Richmond.* | *Upper Richmond.*

Cambrian. | *Ordovician.*

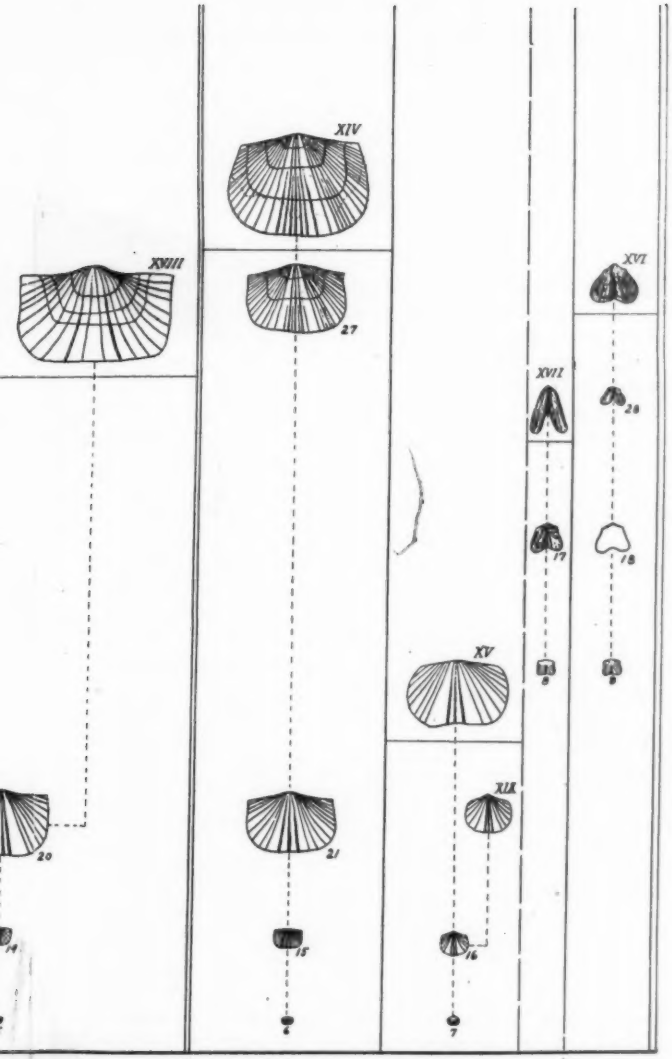
FIG. 27.—Diagram showing adult forms and growth stages of *Platystrophia* for the several geological divisions. Roman numerals (except IV) correspond to those of fig. 26. XVII, *Bilobites strophia lynx*, from the extreme upper Richmond at Richmond, Indiana. VI *a*, Gerontic *P. costata*, from the upper Lorraine. XI *a*, *P. laticosta*, from the lower Richmond, Tanner's Creek, I above horizontal lines; 1–9, nepionic stages; 10–18, neanic stages; 19–28, ephebic stages. The nepionic stage is identical for all except XVII and XVI (8 and 9), where this stage resembles t identical for III to XIII and XVIII (10–14), but change for *P. biforata* (XIV) and *P. dentata* (XV), and again for *Bilobites* (XVI, XVII). XIII and XVI are distinctly retrogressive types. IV, F



er Lorraine. *Lower Richmond.* *Upper Richm*

Ordovician.

veral geological divisions. Roman numerals (except IV) correspond to those of fig. 26. XVII
P. costata, from the upper Lorraine. XI *a*, *P. laticosta*, from the lower Richmond, Tanner's
The nepionic stage is identical for all except XVII and XVI (8 and 9), where this stage res
ata (XV), and again for *Bilobites* (XVI, XVII). XIII and XVI are distinctly retrogressive type



XVII, *Bilobites verneuiliana*, from the Silurian of Gotland. XVIII, *Platy-*
nner's Creek, Indiana. Arabic numerals, ontogenetic stages of adult forms
ge resembles the adult *P. costata* (or *unicostata*). The neanic stages are
e types. IV, Pauciplicate *P. lynx*, homœomorph of *P. dentata*.

ART. XI.—*Note of the Condition of Platinum in the Nickel-Copper Ores from Sudbury;* by CHAS. W. DICKSON.*

THE determination of the new mineral sperrylite ($PtAs_2$) by Professors Penfield and Wells, in 1889,† has led to a great deal of speculation since, as to the condition of platinum in various ores where it is known to occur. This applies especially to the nickel-copper ores of the Sudbury District, Ont., in which a small percentage of the platinum metals seems to be always present.

As originally discovered by Mr. F. L. Sperry, the sperrylite occurred in the loose gossan material, which consisted of gravel containing iron and copper oxides and sulphides, and which was found near a quartz vein at the Vermilion mine in Algoma, Ontario. In 1896, T. L. Walker‡ made some further investigations on this gossan from the Vermilion mine, and decided that the sperrylite occurred in connection with the chalcopyrite, while none could be detected associated with the fragments of pyrrhotite. Summing up, he says: "In this connection it may be mentioned that in all the copper-nickel mines of the Sudbury District traces of the metals of the platinum group are found, and also that the nickel matte from mines low in copper contains very little platinum, while mines richer in copper afford a matte proportionately richer in platinum. In short, the platinum contents of the nickel matte in the Sudbury District is directly proportional to the copper contents; viz., proportional to the amount of copper pyrites in the original ore. This fact, taken in connection with the detection of sperrylite in fragments of chalcopyrite, while a careful search did not reveal it in the pyrrhotite fragments, renders it very probable that the platinum found in the Sudbury District in the copper-nickel mines in general occurs as sperrylite, and that the mineral occurs generally, if not exclusively, in chalcopyrite." Thus, while the opinion has been quite general that the platinum in the unaltered ores of the nickel-copper mines of the Sudbury District was in the form of the arsenide, the matter was not proved directly, and the conviction was inferred only from analogy with the occurrence at the Vermilion mine.

Professor Vogt has recently§ published the results of a number of analyses of various ores from the Norwegian nickeliferous pyrrhotite deposits. He finds that a small but appreciable quantity of the metals of the platinum group is always present. The copper minerals, as in the Canadian occurrences, contain the largest amount. His opinion is that the platinum is present as sperrylite, connected with the chalcopyrite; but this has not as yet been proved, though the results obtained in

* 1851 Exhibition Scholar, from Queen's University, Kingston, Ont.
† This Journal (3) xxxvii, pp. 67, 71, 1889. ‡ This Journal (4), i, p. 110, 1896.
§ "Platingehalt in norwegischen nickelerz.", Ziet. für prak. Geol., Aug. 1902.

the experiments here described give additional weight to his conclusion.

With the object of settling the point, if possible, the present writer began a number of experiments about a year ago, on various samples of ore from the Sudbury District, but without arriving at any conclusive results. Then the discovery of Professors Wells and Penfield,* that the platinum in the copper ores from the Rambler mine, Wyo., was present as sperrylite, led to some further experiments, one of which proved notably successful. As Walker had shown that the platinum was associated with the chalcopyrite, this mineral was selected as the object of special investigation. A number of samples from different localities were freed from pyrrhotite and other foreign minerals as well as possible, and were used for the tests. The only one, however, which gave satisfactory results was some massive and almost pure chalcopyrite from the Victoria mine, about twenty miles west of Sudbury. Seventy-five grams of the coarsely crushed mineral were treated a number of times with hot nitric acid, till all the sulphides were decomposed. The sulphur which separated was removed by means of carbon bisulphide, and the residue treated several times with sulphuric and hydrofluoric acids, to remove the quartz and silicates. The final residue consisted of quite a large number of small and very brilliant tin-white crystals and fragments, resembling sperrylite. On a qualitative examination the mineral proved beyond doubt to be the arsenide of platinum. It yielded a crystalline sublimate of As_2O_3 in the open tube. On long continued treatment with hot concentrated aqua regia some of it was dissolved, and on the addition of ammonium chloride gave the well known yellow crystalline precipitate of ammonium-platinic chloride. The test of dropping some of the fragments on a piece of hot platinum foil was also tried. The mineral melted, sprouted, and gave off white fumes, so there can be no doubt as to its nature, chemically.

Some of the crystals were very well developed, and fifteen or twenty of them ranged between 0·5–1^{mm} in diameter. A number also presented interesting and complicated combinations of forms, and in order to prove the crystallography of the mineral, and to compare it with that from the locality of the original discovery, some of the angles were measured. Nearly all the crystals are more or less distorted; a modified, elongated cube being perhaps the commonest. The largest and most perfect crystal (an elongated cube) had the following faces: cube (001), octahedron (111), pyritohedron (210), and trapezohedron (211), besides some smaller indefinite faces which could not be accurately determined.

The measurements are as follows:—

* This Journal (4), xiii, 95, 1902.

Faces.	Observed Angles.	Calculated Angles.
$100 \wedge 100$	90° 3′	90°
"	90° 1′	"
$100 \wedge 111$	54° 41′	54° 44′ 8″
"	54° 46′	"
$111 \wedge \bar{1}11$	70° 28′	70° 31′ 44″
"	70° 29′	"
$210 \wedge 100$	26° 40′	26° 34′
"	26° 38′	"
$211 \wedge 100$	35° 14′	35° 15′ 45″
"	35° 11′	"

A somewhat smaller crystal yielded a variety of forms, including two trapezohedrons (211 and 411), with the following measurements:

Faces.	Observed Angles.	Calculated Angles.
$211 \wedge 111$	19° 28′	19° 28′ 30″
"	19° 24′	"
$411 \wedge 111$	35° 17′	35° 15′ 45″
"	35° 18′	"

The dodecahedron (110) was also observed on a number of crystals. It was noticed that the octahedral faces gave the best reflections, while those from the trapezohedrons were fainter, and those from the cube were often multiple.

Of the faces found, the trapezohedrons (211 and 411) had not been recognized till the work of Professors Nicol (School of Mining, Kingston, Ont.) and Goldschmidt, during the past summer.* In addition to the forms already described (111, 100, 102 and 110), these workers discovered a large number of new and interesting faces, including the two found on this material. It is thus evident that the sperrylite from the new source and locality (Victoria mine) is identical, chemically and mineralogically, with that as originally described by Professors Penfield and Wells from the Vermilion mine.

While these experiments will not prove that all the platinum is present as sperrylite, they at least remove the doubt as to its condition, in part at least, in the unaltered ore. Even the platinum which has been found in connection with the nickel mineral polydymite will no doubt prove to be present as the arsenide, if enough material can be made available for careful work.†

These experiments were carried on, partly in the laboratory of the School of Mining, Kingston, Ont., which was kindly placed at the writer's disposal, and partly in the laboratories of the Geological and Mineralogical Departments, Columbia University, and thanks are due to Dr. W. L. Goodwin, of Kingston, and Professor Kemp, of Columbia, for facilitating the work. The writer is also indebted to Dr. A. F. Rogers, of the Department of Mineralogy, Columbia, for his kindness in assisting with the goniometrical determinations.

Columbia University, New York, Dec. 12, 1902.

* This Journal (4) xv. † This Journal (3), xxxvii, 67, 1889.

Art. XII. — *Lecture Experiment on Surface Tension and Superficial Viscosity;* by John E. Burbank.

While carrying on some experimental work in regard to the motion of solids in water, the author made a very interesting observation on the elastic properties of liquid surfaces, and as no mention of this particular form of the experiment is to be found in the text-books or magazines at hand, there is presented here a brief description of the experiment for the benefit of those who might wish to use it as a lecture-room demonstration of the properties of liquid surfaces. No attempt was made to take any quantitative measurements of any kind as the experiment was considered merely qualitative. And no figures are given, since any one can readily understand the conditions without them.

A ball of paraffin wax, $4{\cdot}3^{cms}$ diameter, was made as nearly spherical as possible, and a small mass of lead inserted in it so as to keep it in a fixed position and prevent rotation as it moved up or down in a mass of water; by using different amounts of lead it is possible to so adjust the weight of the ball that it will move very slowly. If the ball and counterweight be such that the mean specific gravity of the mass be a very little less than that of water, it will rise with a velocity of from two to ten centimeters per second. If the adjustment be made so that the ball will have an upward velocity of about 4^{cms} per second, and then the ball submerged to a depth of about 40^{cms} in a jar of water and then allowed to rise, on reaching the surface film of the water it raises the latter through a small distance causing it to stretch; the action of the film is to contract and force the ball down into the water to a depth of about 10^{cms}. In many cases the ball would rebound the second, and even the third time, but generally the contamination of the water film by the paraffin caused the surface to break after the second rebound. If the ball be tried repeatedly in the same vessel of water the surface soon becomes so contaminated that only one rebound is observed.

The force of gravity is not the whole cause of this rebound, as we shall see when we consider the rebound of liquid spheres under the same conditions. In order to show that the rebound was chiefly due to the action of the film, the two following tests were made:

1. The height to which the ball rose at the instant of first rebound was carefully noted, then the height to which the ball rose after finally breaking the surface was found to be practi-

cally the same; no allowance could be made, however, for the effect between the film and the paraffin in the last position.

2. After noting the height to which the ball rose at first impact, the ball was removed from the water so as to break the film, then lowered in again to the same height as at impact and allowed to fall. In no case was the distance fallen as great as on rebound from the film. Both of these methods were very rough, and only comparative measurements were taken.

A wooden ball of $3{\cdot}4^{cms}$ diameter, weighted in same way as paraffin, was next tried; the results were of the same nature but not so strong owing to the capillary action of the film on the slightly rough surface of the ball. With this ball it was possible to get velocities sufficient to break the film but no observations were taken in regard to this point.

The paraffin ball was then tried in alcohol and similar results to those in water were obtained. It was next tried in kerosene oil but the clinging of a layer of oil prevented any positive results. It was finally tried in a strong solution of soapy water, which would have a film with great viscosity and small tension; a film of this kind should show a greater rebound than pure water, other conditions being the same, because the actual time interval of contact between the ball and film would be greater than in pure water on account of less tension of film; this greater time interval would allow the eddies in the wake of the ball more time to die out and thus less resistance would be opposed to the rebound. Observation showed that this reasoning was correct, the distance of rebound being decidedly greater than from a surface of pure water.

Liquid spheres rebounding from liquid surfaces.—Kerosene of specific gravity ·78 was run into the bottom of a jar of water about 40^{cms} deep, by means of a long tube ending in a U-shaped capillary small enough so that the drops escaped at the rate of 2 or 3 per second; these drops would rise with considerable velocity and at the very first, while the surface of the water was clean, many of them would rebound, but only through about $1/2^{cm}$; this small rebound is due partly to the difference in density between kerosene and water, but chiefly to the flattening of the drop. After a few drops of kerosene have risen to the surface none of the drops will rebound but the flattening effect is more noticeable; this would also be explained by the longer time interval of contact between drop and film; the shorter the interval of contact the more nearly the drop behaves like a solid sphere, precisely similar to the effect of striking the surface of water with the hand. A jar containing a little water was filled with kerosene, and alcohol of specific gravity about ·81 was run in from a pipette; the rebound of the alcohol from the film between the kerosene and water was very evident;

from the previous reasoning one might expect the viscosity of the film to destroy the rebound, but it is probable that while much of it is destroyed in this way, yet the velocity of the drop and its slight difference in density from the kerosene, make this rebound a maximum. This is an extremely good illustration of the tendency of a liquid to form in drops; if the alcohol be run in in a fine stream it breaks up into numberless drops, and the surfaces of these drops are seen to be in rotational motion; sometimes several of these drops crowd together and fall as a single mass. The next trial was of olive oil in a mixture of alcohol and water having a slightly greater density than that of the oil itself; no rebound was observed, the velocity being very small, and the flattening of the drop at impact very pronounced; this observation bears out the reasoning in regard to the action of the kerosene after the surface of the water has been contaminated by the first few drops.

It should be noted that the velocity of a solid sphere falling in a liquid of uniform density becomes constant after a very short interval of time; this has been proved by Allen * and others, and of course the same would apply to a solid sphere if rising; except for the rotational motion it would doubtless apply with similar accuracy to the motion of liquid drops in a fluid of different density. In case a solid sphere is used of nearly the same density as the liquid, a slight change in temperature will made a great difference in velocity of rise, and also in rebounding effect.

Conclusion.—As has been shown by Stokes, to whom reference is made in Allen's paper cited above, there is a certain critical velocity for a sphere moving in a mass of fluid; for velocities above this value, eddying motion is a disturbing factor in the mathematical calculations, for velocities less than the "critical" the mathematical equations hold. From these considerations we might expect that for each sphere there would be a certain "critical" velocity which would depend on the difference in density between the liquid and the sphere, on the nature of the surface of the sphere, and on the surface tension and superficial viscosity of the liquid film; when this particular velocity is attained we would then have maximum force of rebound.

Physical Laboratory,
Univ. of Maine, Orono, Maine.

* Motion of a Sphere in a Viscous Fluid, H. S. Allen, Phil. Mag., l, 1900.

Art. XIII.—*Mylagaulodon, a New Rodent from the Upper John Day of Oregon;* by W. J. Sinclair.

Dr. W. D. Matthew, in his revision of the Mylagauli, enumerates* five species referable to two genera, all of which are either from the Loup Fork or the Deep River beds. No representative of this family has so far been described from the John Day. Two years ago, the members of the University of California party discovered the skull of a small rodent in the uppermost beds of the Upper John Day on Johnson Creek, Wheeler Co., Oregon. The specimen is unique, differing from anything known. It is believed to represent a transitional stage between *Allomys hippodus* of the Middle John Day and the Loup Fork *Mylagaulus*. The type specimen (see fig.) is a poorly preserved cranium (Pal. Museum, No. 1652).

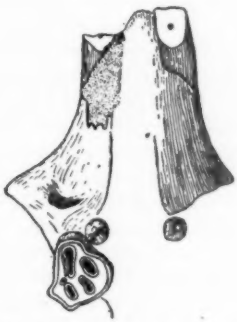


Fig. 1. *Mylagaulodon angulatus*, gen. et sp. nov., Upper John Day, $\times \frac{2}{1}$.

The dentition is imperfectly preserved, but the dental formula was probably reduced below that of *Allomys*. The third superior premolar is a simple cylindrical tooth, as in that genus. The fourth premolar is hypsodont. On the triturating surface of this tooth there are four antero-posteriorly elongated lakes, with a fifth small circular lake situated between and external to the two large outer lakes. On the outer side of the antero-external lake there is a straight enamel ridge narrower than the circular bands inclosing the lakes. This ridge and the small circular lake would probably disappear in the worn tooth. The external side of the crown is flat with a prominent postero-external angulation, which suggested the specific name *angulatus*. The antero-external angle of the crown is rounded.

* Bulletin Am. Mus. Nat. Hist., vol. xvi, pp. 291–310.

There is no trace of cement externally on the crown of either premolar. Molars are not preserved. The poor state of preservation of the cranium prevents a detailed discussion. The infra-orbital foramen is larger than in *Allomys hippodus*, and is situated close to the zygoma.

MEASUREMENTS.

Approximate length of the skull	46	mm.
Length of diastema anterior to pm. 3	11	"
Antero-posterior diameter of enlarged premolar crown	5·5	"
Transverse diameter of enlarged premolar crown	5	"
Antero-posterior diameter of pm. 3	1·5	"
Transverse diameter of pm. 3	1·5	"
Greatest width of incisor	2·5	"

The species is referred to a new genus, *Mylagaulodon*, so named from the resemblance of the enlarged premolar to the teeth of the Mylagauli. In the retention of the conical premolar, the genus resembles *Allomys*, from which it differs in the loss of the antero-external buttress between the outer crescents in the fourth premolar, the rounding of the antero-external angulation, and the hypsodont character of the tooth. A somewhat similar arrangement of the enamel lakes might be attained in worn teeth of *Allomys hippodus*. *Mylagaulodon* is sufficiently contrasted with the beavers in the antero-posterior elongation of the enamel lakes, in which it agrees with *Mylagaulus*, differing from that genus, however, not only in the shape of the fourth premolar, but in the retention of the cylindrical third premolar as in most of the Sciuridæ. It is believed that reduction either in size or number of the molars must have taken place in *Mylagaulodon*, owing to the lack of space on the maxillary to accommodate three more teeth of the same size as the last premolar.

The presence of this transitional form in the uppermost John Day is important in the light of the known occurrence of *Mylagaulus* in the Mascall beds at Cottonwood, Oregon. It is in the Upper John Day that the ancestors of the oldest Loup Fork fauna should be sought with the most confidence. It is possible that the evolution of the Mylagauli took place in the Oregon.

Paleontological Laboratory,
University of California, Berkeley, Cal.

ART. XIV.—*Studies in the Cyperaceæ;* by THEO. HOLM.
XVIII. On *Carex fusca* and *Carex bipartita* All.

THE futile endeavor on the part of certain modern systematists to verify plant-species, established by the earlier authors, by means of their herbarium-specimens but regardless of the diagnoses, has resulted in some very strange discoveries, so strange indeed that they are hardly to be believed. And the excuse for not considering the diagnoses is simply the belief that the herbarium-specimens are to be looked upon as "types" of the respective species. Thus one author states that he "has seen the very oldest types, so far as they are known to exist," of the North American *Carices;* if he had said "supposed to be types" he might have come nearer the truth.

That this kind of work does not fall within the scope of scientific research is certain, and one might think that it should be ignored altogether. But experience has taught us that some of these results have, nevertheless, been accepted by several writers abroad and in this country, and we have thought, therefore, to present some samples of what may be called "type-species botany," for which we have selected Allioni's *C. fusca* and *C. bipartita*, of which the former name has been accepted in the place of the younger *C. Buxbaumii* Wahlbg., while the latter has been applied as the earliest appellation for Willdenow's *Kobresia caricina.*

It would appear at once that the verification of such old species means a good deal more than a hasty examination of the specimens, that no small amount of literary research is involved, a study of the author's method of describing, of citing, the history of the herbarium as it has been left at his death, etc.; the last question is of no small importance, as we shall demonstrate in the following pages. And if these points were duly considered so much stress would not be laid upon "names" alone, as is the case at present and has been, we regret to say, during the last decennium. "Tum primum homines ipsas res neglexerunt, quum nimio studio nomina quærere cœperunt," said Galenus.

Literary research, however, even if it does not reach beyond the history of a plant-name, is of some importance, if properly conducted, but is seldom productive of results commensurate to the time expended. There is another phase of this so called type-species botany which is especially objectionable; this is the confusing results which ultimately arise as a consequence of taking certain specimens to be types whether they agree with the diagnosis or not. In the latter instance a diagnosis

may look as if it were entirely wrong; thus we might infer that the author—he be an Allioni, Linnæus, Willdenow, Robert Brown or anyone whose specimens have fallen into the hands of "type-species botanists"—did not know how to describe a common plant. Thus is the "type" of Robert Brown's *Carex affinis* said to be *Kobresia scirpina* L.,* although Robert Brown's diagnosis calls for a *Carex*, and although he enumerates the Kobresia in the same list identified as a Kobresia. It would hardly be probable to suppose that Robert Brown should have made a *Carex* out of this genus after he had examined and identified other specimens as a *Kobresia;* it seems much more reasonable to believe that the plant Professor Bailey saw was either not a *Kobresia*, or that the specimens were not Robert Brown's type; the latter conclusion is more natural inasmuch as Robert Brown did not work with types. Another example may be mentioned in regard to suppressing Dewey's *Carex petasata:* "The original sheet is in Herb. Torrey. It contains 3 plants, *C. lagopina*, *C. festiva* and *C. Liddoni*, to all of which Dewey's description will equally apply." And, therefore, *C. petasata* "cannot be pressed into service"! This is evidently one of the farthest points to which "type-species botany" has reached, when we consider the fact that the name *C. Preslii* is preferred for this species, although with the admission that it is a "guess name," and that Dewey sent good examples of his *C. petasata* authenticated by his hand to Bcott, who had them figured, and our friend Mr. C. B. Clarke of Kew has informed us that these specimens were "not mixed." Drejer's *Carex hyperborea* is, regardless of the diagnosis and opinions expressed by Blytt, Elias Fries and other critical students of the genus, simply referred to *Carex vulgaris* on the grounds that some few mounted specimens were taken to be "the type." These are only a few out of many cases where specimens have been given preference to the diagnosis and the result is, of course, not unexpected. And the difficulty which confronts us when studying certain plants in the earlier herbaria lies in the fact that, as a rule, we know so very little about the real history of these herbaria. One thing, however, should be readily emphasized from the study of the old literature, that the botanists did not work with types, and it requires, indeed, but very little research to make us feel convinced of that. Moreover, there is no indication whatever to prove that the specimens preserved in these old herbaria are those that served as base for the diagnosis.

It might be of some interest to the reader when we present

* For references consult the Bibliography appended to this paper.

a brief sketch of certain points relating to the herbaria of Linnæus and Willdenow so as to demonstrate the fact that it is pure imagination to believe that the specimens preserved are "the types of the species." The Linnæan herbarium has been thoroughly studied and its actual importance been explained by various authors, for instance by Elias Fries and Hartman. We owe to the former an excellent account of the condition of the herbarium, about Linnæus' method of collecting, citing, etc., and Hartman has given a report in full about the Scandinavian plants that are represented in the herbarium. It is a well known fact that a large number of the specimens collected by Linnæus do not correspond with the diagnosis, written by himself, and the reason for this is, thus, explained: Linnæus did not preserve such material as he had already described, and which he described in the field, but he preserved such specimens which were either very rare and not readily accessible or such as he thought differed somewhat from those already described. These he laid into the herbarium with the intention of comparing and studying them later. It is, thus, the fact that almost none of the plants which Linnæus mentions in his narratives of his journeys are preserved from these stations, but that they are represented by specimens from entirely different places or countries, which seems to prove that Linnæus' writings were not based upon "herbarium-specimens," but upon studies in the field. Linnæus' quotations are mostly misunderstood. He explains himself, however, that these do not necessarily need to indicate that the plants are identical, but that the figure—and he refers mostly to figures—does give some idea of the habit and to some extent expressing the general aspect of the plant. It is, thus, evident that Linnæus' species must be studied by means of his diagnosis and not from the specimens or quotations, and this is, of course, in many instances quite a difficult task.

However some, and indeed no small, assistance is rendered by the fact that Linnæus did not enumerate and describe his species "haphazard," but that he followed certain rules in the disposition of these. One of these principles adopted by Linnæus is for instance noticeable in the description of the species of *Stellaria*, where he commences with the one that possesses the broadest leaf and ends with those of which the leaves are the smallest and narrowest: 1. *Stellaria nemorum* "foliis cordatis," 2. *S. dichotoma* "f. ovatis," 3. *S. radians*, "f. lanceolatis," 4. *S. graminea* "f. linearibus" and 5. *S. biflora* "f. subulatis." His arrangement of the *Carices* follows a similar principle, though especially applied to the composition of the inflorescence: *Carex dioica* "spica simplici, dioica," *C. capitata* "spica simpl. androgyna," *C. baldensis* "spicis

androgynis," *C. flava* "spicis sexu distinctis," etc. By studying these various rules followed by Linnæus in disposing of the species, we have often succeeded in identifying several of his critical species.

But the assumption that Linnæus should have intended the first species in each genus as being the generic type, has no foundation; his classification of species seems to us too artificial, as stated above, but has the advantage, on the other hand, of being an excellent guide for determining his species. There are so many variations in his rules for arranging the species, that no critical reader should ever get the impression that the first species was intended to be the type of the genus; sometimes the largest and highest developed species, for instance in *Stellaria*, is the first enumerated, or the lowest one as in *Carex;* a most complicated classification is exemplified in his *Amaryllis* and many others, where no attempt has been made to classify the species in anything like a phyletic order, but only in such a way that the determination may be rendered as easy as possible. The principles of Linnæus for the establishment of the genera and species must be studied in his Philosophia botanica, where he gives a complete account of the various characters, their meaning and respective importance.

We will now proceed to give a few remarks upon the very comprehensive herbarium of Willdenow in accordance with the criticism offered by Schlechtendahl. We need simply to repeat that most important information that Willdenow's herbarium does not contain specimens of all the species which are enumerated in his Species plantarum. This is readily to be seen from the fact that Willdenow, who made very extensive exchanges with other botanists, very often removed the original specimens when he received better, more completely preserved ones of what "he took to be" the same species. In a number of cases they were not the same, and the original ones were sent out in exchange for others. Furthermore that Willdenow, like Linnæus, put many plants in his herbarium "ad interim" under certain species, which he desired to keep for future studies, but many of these were never studied or more carefully compared. Last, not least, when Willdenow died a number of specimens and labels were mixed in such cases, where more than one had been laid on the same sheet. Willdenow's herbarium must, therefore, always be treated with the greatest precaution when the intention is to match his species in the herbarium with the diagnoses of the respective species in his Species plantarum, with the only exception of the Ferns, which are said to have been left in good order and so far undisturbed. So much concerning Willdenow's herbarium, which

certain authors generally agree to consider as being a collection of real "types." It is more than probable that several of the other old herbaria were founded and kept in the same way, but we know so very little about them, and we suggest that the specimens therein preserved should not be given preference for the diagnosis; we might cite here the words of the German botanist Koch, that he desired his species identified not by his herbarium, but by his diagnoses. Nevertheless several modern writers believe in "old types" and that "type-species botany sometimes is our surest way of settling a hard point."

We have, as indicated in the title of this paper, the intention to present some views regarding two *Carices* of Allioni, which seem, in later years, to have been entirely misunderstood, and which have now been restored in such a way that their names have been applied to two plants, regardless of the fact that the restoration is inconsistent with the diagnosis and the geographical distribution. Let us begin with *Carex fusca* All., which is now recognized as identical with *C. Buxbaumii* of Wahlenberg. As security for the correctness of this identification the following statement is offered: "Although Allioni places this species in the section characterized by spicis pluribus sexu distinctis mare unica, it has an androgynous terminal spike. It is represented by a good specimen." And on the strength of this, we might say very unimportant fact, *C. Buxbaumii* is nowadays called *C. fusca* All. by a number of writers in this country and abroad. Any botanist who is familiar with the work of Allioni, with geographical distribution of plants, and with the literature bearing upon the genus *Carex*, will realize at once the ambiguity of the above statement.

Allioni followed the same principle as Linnæus in describing the species of *Carex;* he commenced with those species in which the inflorescence is "spica unica," after which follow those in which there are several androgynous spikes (*C. tripartita*, *arenaria*, etc.), thereafter those with "spicis pluribus sexu distinctis, mare unica," among which we find *C. fusca.* If the plant which Allioni had in mind had been the real *C. Buxbaumii* he surely would have placed it among those with one terminal, gynæcandrous spike and several lateral, pistillate ones, but he has no member of this group. His diagnosis calls for a plant with one single staminate and three pistillate spikes, while the specimen preserved is said to have a gynæcandrous (androgynous) spike. The question is now to decide whether Allioni made a mistake in his diagnosis, that he overlooked the pistillate flowers in the terminal spike, or whether the specimen in his herbarium was not considered in his

description of the species. We know nothing certain about the matter, but it would be illogical to suppose that Allioni could make such a mistake, when we remember that he is the very author himself of several critical species of *Carex* that are much more difficult to describe than *Carex Buxbaumii*. There is, so far, absolutely nothing to justify us in assuming that the specimen of *C. Buxbaumii* was preserved as the type of *C. fusca*. If it really were the case, we should expect to find citations in the works of other authors who were familiar with Allioni's work and his herbarium; but there are no such citations of *C. fusca* as being identical with Wahlenberg's *C. Buxbaumii*, since the latter has never been known to be common on the Alps of Piemont; as a matter of fact it has never been found there.

It is, for instance, very strange that Schkuhr does not refer to Allioni's plant, but that he established a *C. fusca* of his own; he does not appear to have known *C. Buxbaumii* either, since he describes this as his *C. polygama*, making no allusion whatever to Allioni's plant. The same with Willdenow, who describes *C. Buxbaumii* but without any reference to *C. fusca* of Allioni. First, Gaudin does enumerate Allioni's species, quoting Haller's diagnosis, to which Allioni refers, and Gaudin considered *C. fusca* to be either *C. rigida* Good. or a variety *nigrior* of *C. cæspitosa* L.; the latter plant is among those which Haller's pupils collected, and this is, perhaps, the plant Allioni had in view. Bertoloni in his work upon the Flora of Italy makes no mention neither of *C. fusca* All. or of *C. Buxbaumii* Wahlbg. But finally in Parlatore's Flora Italiana do we learn that *C. Buxbaumii* is a welcome acquisition to the Flora of Italy, having been discovered near Bolzano, but with no reference to its supposed earlier stations in Piemont. If Parlatore had recognized Allioni's *C. fusca* as identical with *C. Buxbaumii*, he would surely have referred to Allioni's species and stated its occurrence "frequens in alpibus, quæ monte Vesulo et Cenisio intercipiuntur." But Parlatore does not give us any information about *C. fusca;* would it not be more correct to surmise that the identity of this species is obscure? Neither Schkuhr, Bertoloni, Parlatore or Willdenow seem to have been able to determine this plant with certainty, and these authors were very familiar with the work of Allioni. It is true that *C. Buxbaumii* does sometimes occur with the terminal spike purely staminate instead of gynæcandrous, yet the plant described by Parlatore (l. c.) is the typical form; the latter, and the specimen, if correctly identified, in Allioni's herbarium has, also, a gynæcandrous spike. Let us presume that even if the specimen in the herbarium be the true *C. Buxbaumii*, that the specimen was not the plant

which Allioni described inasmuch as he immediately after *C. fusca* describes his *C. trigona*, which has been identified as the well-known *C. fulva* Good.

The second example is *Carex bipartita* All., which is now by the same writer explained as *Kobresia caricina* Willd. with the interesting statement that the same species is labeled *C. bipartita* in the herbarium of Balbis, and that its history is clear!—

We regret to say that we have not succeeded in determining the identity of this second species of Allioni with absolute certainty, but the result of our study of the literature seems to be more in favor of it being a true *Carex* than a *Kobresia*, judging from earlier authors who were familiar with Allioni's herbarium. Let us read these authors and let us never forget that we at present have no knowledge whatever of the real conditions of Allioni's herbarium. Allioni described his plant as a species between *Carex arenaria* and *C. paniculata*, where he would hardly have placed his *C. bipartita* if it had been a *Kobresia*; his illustration is not good as a figure of "*Carex lagopina*," but it would be worse, if it were a *Kobresia*. It was Willdenow, who established the genus *Kobresia* and in enumerating the species, among which *K. caricina*, he makes no allusion to *C. bipartita* All. He cites, however, *C. lacustris* Balbis in litt., and as we are told by Professor Bailey, Balbis' specimens are *Kobresia caricina*. It is now interesting to read Gay's account of *Carex lagopina* Wahlbg., since Gay refers as a synonym Allioni's *C. bipartita*, his determination being based upon Allioni's diagnosis, while he states at the same time that Balbis' specimens in the herbarium of Desfontaines contain both this and the *Kobresia*. But Allioni's species was founded upon Bellardi's plants, and these have been verified as *C. lagopina* Wahlbg. by Parlatore (l. c.) This author, who describes both *Kobresia caricina* and *Carex lagopina*, prefers to consider Allioni's plant identical with the latter, on account of the specimens collected by Bellardi.

That Bertoloni (l. c.) enumerated Balbis' specimens as *Kobresia* was evidently due to the fact that the specimens were mixed, as stated above, and he evidently received some specimens of *Kobresia* only. If we now consider these various phases of the question, it seems as if the identification of Bellardi's specimens as *Carex lagopina* is of greater importance than the fact that Balbis collected the same plant, but mixed with *Kobresia*. The specimens collected by Bellardi, not by Balbis, were those upon which Allioni founded his *C. bipartita*, now known as *Carex lagopina* Wahlbg., and this together with the statements from the literature is a point

which heretofore has been overlooked or, perhaps better, been entirely ignored.

The study of the old authors requires much more than a superficial determination of their herbarium-specimens, and no such research should ever have any bearing upon our knowledge of the old masters, their methods of describing, of preserving their plants, etc. We hope that the few points we have discussed in the present paper will be instrumental in suggesting to the systematists the exercise of greater care in accepting new names or combinations as are offered by writers, who have demonstrated their incompetency in studying the old herbaria and interpreting the literature. There seems, so far, no reason to reject *C. Buxbaumii* Wahlbg. and *Kobresia caricina* Willd., and the same result would, no doubt, be reached if we submitted most of the other new combinations to a similar treatment.

Brookland, D. C., October, 1902.

Bibliography.

Allioni, C.: Flora Pedemontana, 1785, vol. ii, pp. 265 and 269.

Bailey, L. H.: Studies of the types of various species of the genus *Carex*. (Mem. Torr. bot. club., vol. i, 1889, p. 63.)

Bertoloni: Flora Italica, 1854, vol. x, pp. 156 and 161.

Brown, Robert: Plants from the appendix to Captain Franklin's narrative, 1823, p. 516.

Fries, Elias: Væxternas vetenskapliga namn. Botaniska utflygtar. 1853, vol. i, p. 215.

Gaudin, J.: Agrostologia Helvetica, 1811, pp. 107 and 190.

Gaudin, J.: Flora Helvetica, 1830, vol. vi, p. 70.

Gay, I.: De Caricibus quibusdam minus cognitis, vel novis. (Ann, d. sc. nat. Bot., ser. 2, vol. xi, 1839, p. 177.

Hartman, C.: Anteckningar vid de Skandinaviska væxterna i Linné's Herbarium. (Kgl. Sv. Vet. Akad. Hdlgr., 1849, p. 147.)

Parlatore: Flora Italiana, vol. ii, 1852, pp. 141 and 161.

Schlechtendahl: Einige Worte ueber das Willdenowsche Herbarium so wie ueber die Kgl. Pflanzensammlung zu Berlin. (Flora Jahrg., 15, vol. ii, 1832, p. 561.)

Willdenow, C. L.: Species plantarum, 1805, vol. iv, pp. 206 and 252.

SCIENTIFIC INTELLIGENCE.

I. Chemistry and Physics.

1. *Artificial Diamonds from Fused Silicates.*—Since it seemed probable that natural diamonds have been formed by crystallization from silicate magmas, it occurred to R. v. Hasslinger, that they might be prepared artificially in this way. A mixture corresponding to the analysis of a diamond-bearing breccia (SiO_2, 40·30; Al_2O_3, 9·45; K_2O, ·90; Na_2O, 4·93; Fe_2O_3, 7·30; MgO, 21·10; CaO, 3·48; loss by ignition, 13·00) was found to be too infusible when the usual methods of heating were used, hence the method of Goldschmidt, the so-called "thermite" process, was employed. Instead of magnesium and aluminum oxides in the mixture which has been given the corresponding amounts of the metals were used, and an amount of ferric oxide sufficient to oxidize them was added. To this mixture carbon was added at the rate of one or two per cent, best in the form of very fine graphite. Portions amounting to about 300^g of this mixture were placed in Hessian crucibles, surrounded by ashes and sand, and ignited, with the result that satisfactory fusions were produced by the reaction and diamonds were formed in the fused mass. It was found impossible to detect the diamonds in thin sections of the slag, because, on account of their hardness, they were broken out in grinding. The mass was accordingly dissolved in a mixture of ammonium fluoride and sulphuric acid, and the insoluble residue was examined. Absolutely colorless and transparent octahedrons were found, having an average diameter of ·05^{mm}. They scratched ruby and were combustible when heated with oxygen. The results appear to strengthen the theory that natural diamonds have been formed by crystallization from silicates. It should be stated that the metallic iron produced in the experiments was found to contain carbon only in the graphitic and amorphous forms.—*Monatshefte*, xxiii, 817.

H. L. W.

2. *Fluorescence and Phosphorescence of Diamonds.*—Marckwald has observed that the rays emitted by polonium (now called radio-active tellurium; see the following notice) induce fluorescence in diamonds. Rosenheim has examined this behavior with diamonds from various localities, and finds that all of them show this property. In this way diamonds could be distinguished from other precious stones, such as ruby, emerald, zircon, topaz, opal, etc. For these experiments the bismuth rod coated with a radio-active substance, recently described by Marckwald, was placed close to the objects, and observation was made in total darkness. The rays emitted by diamonds, under the influence of the rod, act upon the photographic plate, even after an exposure of only two minutes. The rays from the rod also act upon the plate, but these are readily cut off by the interposition of substances such

as tissue paper, celluloid, gutta-percha, and glass, while the rays induced in the diamond show much greater penetration and pass through substances a few millimeters thick. It was found that certain diamonds which phosphoresce after exposure to sunlight or magnesium light, produce no action upon the photographic plate when thus phosphorescing, although the light thus produced, as far as could be judged by the eye, was as great as that induced by the radio-active substance.—*Chem. News*, lxxxvi, 247. H.L.W.

3. *Radio-active Tellurium.*—A short time ago, as noticed in the preceding volume of this Journal (p. 303), MARCKWALD announced that he had separated the radio-active element (polonium) associated with the bismuth derived from the pitchblende of Joachimsthal. This was accomplished by the electrolysis of the bismuth chloride solutions, or more satisfactorily by placing rods of pure bismuth in such solutions. Marckwald has now found that the element thus precipitated corresponds to tellurium as far as its chemical properties have been investigated. To precipitate the tellurium he now adds to the hydrochloric acid solution of bismuth a few drops of stannous chloride solution, and, after warming for a few hours, filters off the resulting black precipitate. This has been found to be more active than the product obtained by the other method, while the residual bismuth salt is almost inactive. The amount of tellurium found was very small, scarcely amounting to one ten-thousandth of the bismuth salt used.—*Berichte*, xxxv, 4239. H. L. W.

4. *Action of Hydrochloric Acid upon Aluminum, Chromium, and Ferric Sulphates.*—By dissolving the sulphates under consideration in strong hydrochloric acid, RECOURA has obtained, upon cooling the solutions, the compounds $AlSO_4Cl{\cdot}6H_2O$, $CrSO_4Cl{\cdot}6H_2O$, and $Fe_2(SO_4)_3{\cdot}H_2SO_4{\cdot}8H_2O$. The results show a marked difference in behavior between the ferric salt and the other sulphates. The chromium compound is interesting from the fact that when dissolved in cold water it gives no immediate precipitate with silver nitrate, although the sulphate radical is entirely precipitated at once by means of barium chloride. When the chromium compound is heated for some time at 85° it loses a molecule of water and changes to $CrSO_4Cl{\cdot}5H_2O$. This compound also gives no immediate precipitate with silver nitrate, and, moreover, in very dilute solution it gives no precipitate with barium chloride. The results indicate that the chromium salt with six molecules of water holds the chlorine atom in a complex radical, while the sulphate group ionizes, and that the loss of a molecule of water puts the sulphate group also into the complex radical. The aluminum compound is considered by the author as analogous to the first chromium salt, although it shows no evidence of the existence of a complex radical upon solution in water. —*Bulletin*, xxvii, 1155. H. L. W.

5. *Alkali-metal Hydrides.*—The fact that MOISSAN had prepared a potassium hydride with the formula KH was mentioned in this Journal last year (vol. xiii, p. 240). This author has re-

cently given fuller details in regard to the substance, and has described also the corresponding sodium compound NaH. These hydrides are colorless, transparent and crystalline, and are formed by the action of hydrogen upon the metals at about 360°. At higher temperatures they are decomposed into their elements. They are exceedingly sensitive towards moisture, and are very active chemically. Potassium hydride takes fire when exposed to oxygen at ordinary temperature, while both hydrides ignite spontaneously in chlorine gas. When this combination with chlorine takes place the sodium compound gives a blinding light, and the temperature produced is sufficient to volatilize the sodium chloride which is formed.—*Bulletin*, iii, xxviii, 1140.

H. L. W.

6. *Combustion of the Three Varieties of Carbon.* — MOISSAN has found that diamonds become incandescent in oxygen from 800° to 875°, samples of graphite at about 650° to 700°, and amorphous carbon, according to its character, from 300° to 500°. In each case, however, slow combustion began at a temperature far below that of vivid incandescence; slow formation of carbon dioxide was observed with diamond at 720°, with graphite at 510°, and with a certain soft variety of charcoal at a temperature as low as 100°. Experiments made with this charcoal in contact with oxygen in sealed tubes, in one case for the space of a year in the dark and in another case in sunlight during the month of September, gave no evidence of slow combustion at ordinary temperatures, for no carbon dioxide was detected.—*Comptes Rendus*, cxxxv, 921.

H. L. W.

7. *Ammoniacal Cupric Chlorides.* — By the action of liquid ammonia upon anhydrous cupric chloride, BOUZAT has prepared a blue compound, $CuCl_2 \cdot 6NH_3$. This has a dissociation tension of 760^{mm} at 90°. From this substance, by loss of ammonia, a blue compound, $CuCl_2 \cdot 4NH_3$, and a green one, $CuCl_2 \cdot 2NH_3$, are produced. The first of these gives a tension of 760^{mm} at 140°.—*Comptes Rendus*, cxxxv, 292.

H. L. W.

8. *Peculiar Radiation Phenomenon.* — Many observers have noticed a blackening of photographic plates in the dark, under the influence of certain metals and organic bodies. J. W. Russel attributes the action to superoxide of hydrogen. L. GRAETZ has confirmed, in general, the observations of Russel. The latter maintains that the action, although it penetrates various solid organic substances and certain fluids, is not of the nature of a radiation. Graetz does not agree with this conclusion, since the action appears to penetrate thin metallic layers. Aluminum foil, of the thickness employed by Lenard in his research on the cathode rays, is transparent to the action. One also obtains the peculiar radiation if one blows away the vapor of the superoxide of hydrogen from the photographic plate. Experiments of this nature show that it is not the vapor merely which produces the blackening. The radiation is either a direct ether radiation or due to radio-active particles. One can therefore speak of H_2O_2

rays. The author describes certain experiments which support this view, and maintains that one thus obtains a photographic image of chemical processes and has, to a certain measure, a distance working of chemical processes. The author suspects that an active material is present in the H_2O_2 to which the radiation is due.—*Ann. der Physik*, No. 13, 1902, pp. 1100–1110. J. T.

9. *Photography of the Ultra-Red Iron Spectrum.*—The photography of the ultra-violet spectra of alkali and alkali earths demands a standard of iron lines. HANS LEHMANN seeks to supply this need, and gives a table of wave-lengths extending from λ=6811·34 to λ=8690·98. The author refers to the remark of Abney that no lines of certain metals were found in the region of the extreme ultra-red which he photographed with his sensitive plates, and to his conclusion that there is an upper limit to their spectra. Lehmann believes that this supposition is more or less confirmed by his observations.—*Ann. der Physik*, No. 13, 1902, pp. 1330–1333. J. T.

10. *Excited Radio-activity and its Transmission.*—Professor E. RUTHERFORD has made an exhaustive study of this subject, and the conclusions from his prolonged investigations are as follows:

(1) Excited radio-activity produced by thorium and radium compounds is due to the deposits of radio-active matter, which is derived from the emanation given out by these bodies.

(2) Excited radio-activity is transmitted by positively charged carriers, produced from the emanation, which travel in an electric field with about the same velocity as the positive ions produced in air by the Röntgen rays. This velocity (about 1·3^{cm} per sec. for 1 volt per cm.) is about the same for the carriers of thorium and radium excited activity.

(3) These positively charged carriers are due to the expulsion of a negatively charged body from the molecule of the emanation.

(4) Evidence is adduced for the view that the easily absorbed and apparently non-deviable rays of radio-active substances are due to the expulsion of charged bodies at a high velocity. The rays are thus analogous to the Canal Strahlen of Goldstein, which Wien has shown to be positively charged bodies projected at a great speed. In the case of the emanations the expelled particles are for the most part negative in sign.

(5) In the case of radium about 5 per cent. of the carriers of excited activity are distributed on the anode in a strong electric field.

(6) The excited radiations from thorium due to a short exposure in the presence of the emanations increase, in the course of several hours after removal, to three or four times their initial value.

(7) The emanations and the matter which gives rise to excited activity are the result of a succession of chemical changes occurring in radio-active matter. In thorium there is evidence of at least four distinct chemical changes.—*Phil. Mag.*, Jan. 1903, pp. 95–117. J. T.

11. *Magnetic Declination Tables and Isogonic Charts for 1902;* by L. A. BAUER. 405 pp., 2 pls. Washington: United States Coast Survey.—The increased demand for magnetic data has led the Coast Survey to issue a book bringing down to date the principal facts relating to the earth's magnetism and to construct new magnetic charts.

12. *Manual of Advanced Optics;* by C. R. MANN. 193 pp., 39 figs. Chicago, Scott, Foresman & Co.—The greater practical value of other branches of physics—electricity and magnetism for example, has resulted in the development of these subjects far beyond that of optics in the average physical laboratory. It is, nevertheless, a fact that whether we consider the beauty of the mathematical demonstrations or the accuracy of the measurements, no subject can surpass optics for quantitative physical work. To one who is interested in pure physics the little book just issued by Prof. Mann will prove most welcome. It attempts to do for optics what Carhart and Patterson's *Electrical Measurements* has done for electricity. There are certain features which deserve special mention. First of all, the logical arrangement of the experiments is evident; they grow one out of another as the student is ready for them. The meaning of "resolving power"—a somewhat mysterious term in the mind of most students—is made perfectly clear when illustrated by the simple experiments outlined in connection with it. Measurements in connection with the phenomena of polarized light are clearly outlined and are accompanied by helpful suggestions. The diffraction grating is developed from the conditions of maximum and minimum illumination from light which has passed through two parallel rectangular slits, and two distinct methods of obtaining its resolving power are described. But perhaps the best feature of the work is its description of the Michelson interferometer. When we consider that over sixty papers have been published, embodying investigations with this apparatus, and about as many more discussing these results, it is obvious that physicists have here a most powerful instrument of research. Heretofore the theory and use of this form of the interferometer was to be found only in magazine articles and in foreign works—sources likely to be unavailable for students' use. The book contains a few errors, which a later edition can easily rectify.—J. S. S., Orono, Maine.

II. GEOLOGY.

1. *United States Geological Survey.*—The following publications have recently been issued:

TWENTY-SECOND ANNUAL REPORT, 1900–01, PT. I. 452 pp., 58 pls., 52 figs. The Director's Report (pp. 1–207) shows increased coöperation with the several states and with different branches of the government service—insuring better work at less expense. The appropriation for the year was $997,310, and the increase in appropriation is shown in an increase in scope and

amount of work done. G. H. ELDRIDGE contributes a paper (pp. 219–452) on the Asphalt and Bituminous Rock Deposits of the United States, in which is discussed in detail the nature of the materials and their mode of occurrence.

TWENTY-SECOND ANNUAL REPORT, 1900–01, PT. II. Ore Deposits, 865 pp., 82 pls., 130 figs. The old Tungsten Mine at Trumbull, Conn., is described by Prof. Hobbs. (See this Journal, xiv, 72.) A Preliminary Report on the Lead and Zinc Deposits of the Ozark Region is made by H. F. BAIN, with an Introduction by C. R. VAN HISE, and chapters on Physiography and Geology by GEO. I. ADAMS. Mr. Bain summarizes his conclusions as to the genesis of these ore deposits somewhat as follows: The metals were originally precipitated from shallow seas by organic matter at the time of the formation of the dolomitic limestones of the Cambro-Silurian, and were afterwards concentrated and redeposited by the action of underground waters in fractured or brecciated zones in the Carboniferous limestones, being altered later by superficial agencies, with oxidation and frequently notable enrichment. The Ore Deposits of the Rico Mountains, Colorado, are described by F. L. RANSOME. The ore of the Rico district, which is mostly argentiferous galena, occurs in a number of different formations, as in fissure veins, in bedded or blanket veins, in replacements in limestone and in stocks. Of these types the second has been the most productive. The bulk of the ore has been found in Carboniferous sedimentaries which lie in the central portion of the domical uplift of the Rico Mountains. The area has produced about $10,000,000 worth of ore in the twenty-one years of its existence. At present little mining is being done, and the future of the district is somewhat problematical. Geology and Ore Deposits of the Elkhorn Mining District, Montana, is the subject of a paper by WALTER HARVEY WEED and JOSEPH BARRELL. The Elkhorn district lies on the border between a great granite area and an area of folded sedimentaries. The ore bodies are saddle deposits formed in pitching arches beneath a bed of impervious slate and in a dolomite marble. The deposits were mainly due to the gradual replacement of the dolomite by the substances brought up along a zone of crushed rock by uprising siliceous waters. The metallic contents of the deposit are believed to have come from a gabbro intrusion underlying the limestone. The ore was chiefly a silver carrying smaller values in gold, lead and copper, and was free milling and rich near the surface, but became refractory and of poorer grade in depth. Work in the district was discontinued in 1900. The Gold Belt of the Blue Mountains of Oregon is described by WALDEMAR LINDGREN. This district, situated in the northeastern part of Oregon, forms the most important gold field of the state, yielding at least three-fourths of the total output. The Blue Mountains consist of several cores of old sedimentaries, surrounded by late lavas and igneous rocks of varying types. It is in these old cores that the greater part of the gold and silver

veins of the district are found. The primary deposits are usually normal fissure veins carrying gold, or sulphurets containing gold or silver, or both native gold and sulphurets, in a gangue of quartz. In 1899 the production of the district had a value of something over one million dollars, and the total production up to that time is estimated at a little more than eighteen millions. JOSIAH EDWARD SPURR discusses The Ore Deposits of Monte Cristo, Washington. The mining camp of Monte Cristo is situated on the western slope of the Cascade Range. The rocks of this district are of various igneous types, all belonging to the Tertiary age, along the joints and fractures of which the ores have been deposited. The ores are most abundant near the surface, and the ore minerals show a rough succession from the surface downwards of galena, blende, chalcopyrite, pyrite and arsenopyrite. The upper sulphide zone, which contains the most and the richest ore, was deposited, largely at least, by descending waters. W. E. F.

TWENTY-SECOND ANNUAL REPORT, 1900–01, PT. III. Coal, Oil, Cement, 742 pp., 53 pls., 69 figs. The geology, production, history, etc., of the various coal fields of the United States, including Alaska, are described by experts familiar with the local conditions (pp. 1–571); M. L. Fuller describes the Gaines oil field of Pennsylvania (pp. 529–627); the hydraulic cement industry of Michigan is discussed by Prof. Russell (pp. 635–683); and J. A. Taff contributes a paper on the Chalk of southwestern Arkansas (pp. 693–742).

WATER SUPPLY AND IRRIGATION PAPERS. The following numbers in this series have been issued recently:

Nos. 58.—Storage of Water on Kings River, California; by J. B. Lippincott; 99 pp., 32 pls.

59.—Development and application of Water near San Bernardino, Colton and Riverside, California; by J. B. Lippincott. Part I, 95 pp., 11 pls., 14 figs.

60.—Part II of No. 59; 34 pp.

62 and 63.—Hydrography of the Southern Appalachian Mountain Region; by Henry A. Pressey; 181 pp., 44 pls.

64.—Accuracy of Steam Measurements; by Edward C. Murphy; 95 pp., 4 pls., 30 figs.

65.—Operations at River Stations, 1901, East of Mississippi River; by F. H. Newell; 224 pp.

66.—Operations at River Stations, 1901, West of Mississippi River; by F. H. Newell; 178 pp.

67.—The Motions of Underground Water; by Charles S. Slichter; 101 pp., 8 pls., 50 figs.

68.—Water Storage in the Truckee Basin, California–Nevada; by L. H. Taylor; 87 pp., 8 pls., 20 figs.

69.—Water Powers of the State of Maine; by Henry A. Pressey; 117 pp., 14 pls., 12 figs.

70.—Geology and Water Resources of the Patrick and Goshen Hole Quadrangles, Wyoming–Nebraska; by George I. Adams; 47 pp., 11 pls., 4 figs.

71.—Irrigation Systems of Taxes; by Thomas U. Taylor; 127 pp., 9 pls., 27 figs.

72.—Sewage Pollution in the Metropolitan Area near New York City; by Marshall Ora Leighton; 72 pp., 8 pls., 4 figs.

74.—Water Resources of the State of Colorado; by A. L. Fellows; 147 pp., 14 pls., 5 figs.

2. *Glacial Formations and Drainage Features of the Erie and Ohio Basins;* by FRANK LEVERETT. U. S. Geol. Survey Mon. xli, 781 pp., 26 pl., 8 figs.—The work of Leverett on the Pleistocene deposits of the Great Lakes region constitutes one of the chief contributions to the geology of the United States. Monographs xxxviii and xli are supplementary, the latter describing the area between central Indiana and the Genesee valley of New York. Chapters ii and iii contain a description of the physical features of the region and a discussion of the changes which have occurred in the drainage systems—notably those of the Ohio and its northern tributaries.

The southern border of the glacial drift is found to be not a unit but formed by sheets of widely different ages. The oldest deposit—Kansan or pre-Kansan—is restricted mainly to northwestern Pennsylvania. This sheet consists of a stony till whose great age is determined by the advanced stage of weathering of its pebbles, and also by its erosion. The outwash from the Kansan deposits remains as terraces along the upper Ohio and its tributaries. The second drift sheet—the Illinoian—presents a remarkably flat surface, extending as a fringe ten to sixty miles wide in front of the Wisconsin drift. It has not been found farther east than Holmes County, Ohio.

Following the Illinoian glaciation came the Sangamon and the Peorian interval of deglaciation, separated by the Iowan drift sheet and the main loess deposits. (Complete descriptions with analyses, etc., of these deposits are given in Mon. xxxviii.) The principal drift of the Erie and Ohio basins is Wisconsin, and particularly of the late Wisconsin stage. This is marked by strong moraines on lowland and upland alike, and is described in detail as the morainic systems of the Miami, the Scioto, and the Grand River lobes.

Mr. Leverett discusses in detail (pp. 710–775) the glacial lakes Maumee, Whittlesey, and Warren, which formed in front of the retreating ice sheet as it withdrew into the Huron and Erie basins. The ancient shore lines and outlets have been located with great care. It is shown that the beaches in the eastern part of the Erie basin display a marked warping in contrast to the nearly horizontal attitude of those farther west.

3. *Les Variations periodiques des Glaciers;* par FINSTERWALDER et MURET. 7me Rapport Com. Int. des Glaciers. *Rapport sur Glaciers Français de 1900 a 1901;* par M. W. KILIAN: *Révue de Glaciologie;* par CH. RABOT. 92 pp., 3 pls. (Club Alpin Français. Vol. xxviii.)—The glaciers of the Swiss Alps all show a decrease during 1901 except the Boveyre glacier in the Entre-

mont valley. In the eastern Alps, of the fifty-five glaciers studied, the Vernagt of the Oetzthal is the only one of importance which has lengthened. This glacier has grown remarkably during the past fifty years, and in 1901 advanced fifty meters. The retreat of glaciers in the Italian Alps continues, and several small ones have disappeared. The glaciers of the French Alps show an increased rate of retreat in 1901, and those of the Chambeyron massif are destined soon to disappear. The Marinet group, in spite of successive advances and retreats, is shown by Kilian to have suffered gradual shortening since the Pleistocene. The Alps at the present time offer unequalled opportunity for studying recent glacial work. Speaking generally, the glaciers of other parts of the world were likewise decreasing during 1901.

4. *The Cause of the Glacial Period;* by H. L. TRUE. 174 pp., illustrated. Cincinnati: The Robert Clarke Co.—Dr. True has prepared an interesting summary and discussion of the current theories regarding the cause of the ice age and presents one of his own, viz: that there was a sudden toppling of the earth due to overweighting of certain parts.

5. *Tooth Characters and Revision of North American Species of the Genus Equus;* by J. W. GIDLEY. Bull. American Museum of Nat. Hist., vol. xiv, pp. 91–141, New York.—Among the many examples of evolution based on fossil material, that of the horse is one of the best known and, to most minds, striking and interesting. From the historical point of view it is also of deep interest as having been the first example in which a complete demonstration of an evolutionary process was ever made. Inseparably linked with the working out of this problem are the names of Huxley, Marsh, and Kowalewsky. And the types perhaps historically most important are those of Marsh in the great collections bequeathed by him to the Museum of Yale University. But it is to be noted, however, that these earlier demonstrations were confined to the more salient facts. The methods of more thorough and systematic collection developed within recent years have rendered it possible to work out the finer details of this evolutionary process, and now promise to place us in possession of the actual specific descent of the several lines of horses. In the contribution before us, Mr. Gidley has determined with exactness the various extinct species of the genus Equus, a most difficult and necessary preliminary to the larger problems of descent. He has been able to do this by investigating in a far more thorough manner than has ever hitherto been attempted, the complicated process of individual tooth change. His further investigations of these problems, based on the splendid collections he has made for the American Museum in the past few years, will be awaited with much interest. W.

6. *The Evolution of the Horse;* by W. D. MATTHEW. Supplement to the American Museum Journal, vol. iii, No. 1, Jan. 1903.—A popular exposition of the evolution of the horse, which is evidently based upon and called forth by these later discoveries and researches of Mr. Gidley, as reviewed above. W.

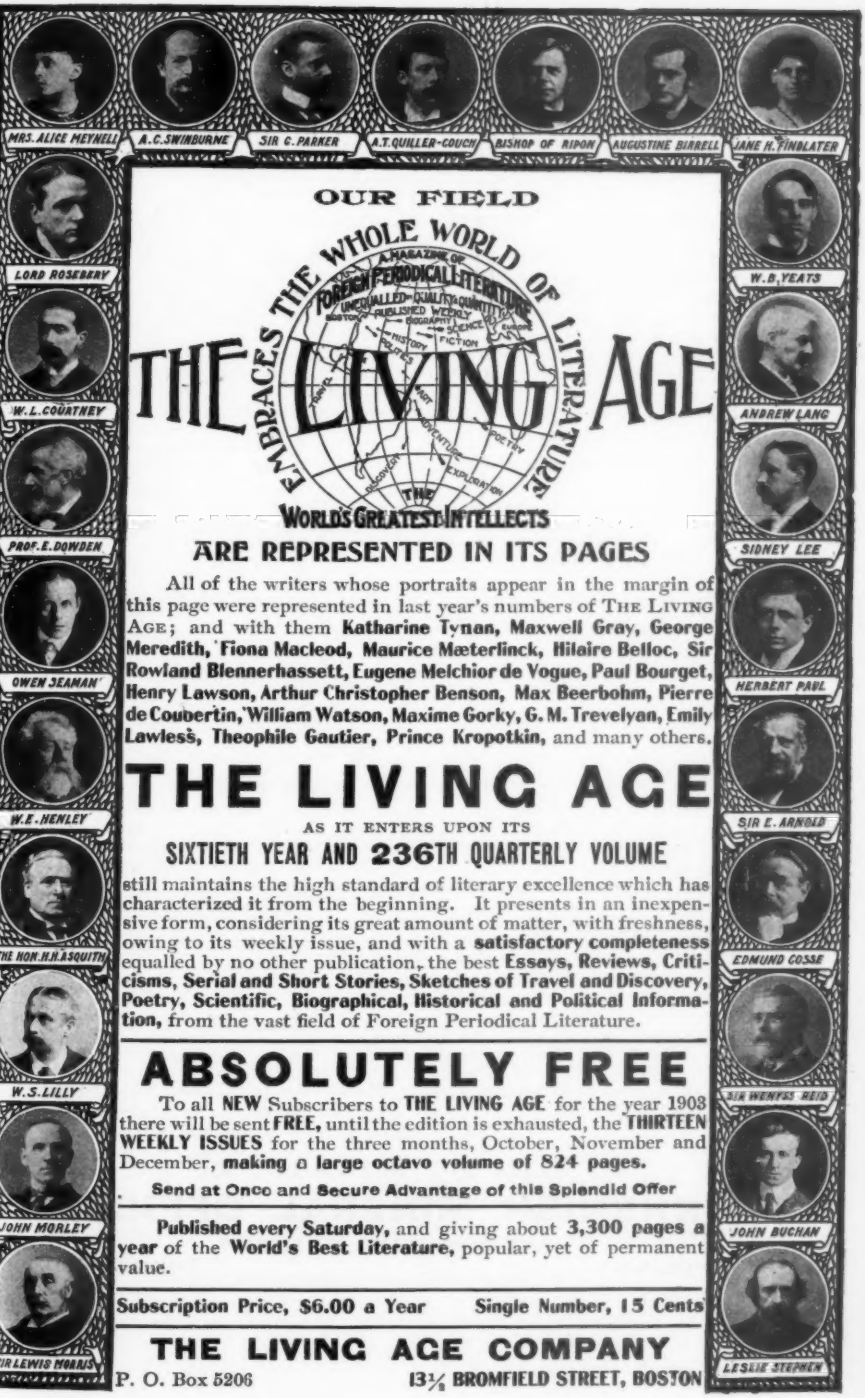
III. Miscellaneous Scientific Intelligence.

1. *Publications of the West Hendon House Observatory, Sunderland;* by W. T. Backhouse. Vol. ii, 4to, 161 pp., 60 illustrations. (Hills & Co., Sunderland.) — The first part of this volume is a continuation of the publication which appeared in 1891, "On the Structure of the Sidereal Universe." These include both the observations by the author and discussion by him of the work of others on the forms and groupings noted in the Milky Way, with such structural features as can be observed in other parts of the heavens, including lines and parallelisms, radiated systems of stars, and rifts, of which latter, analogous to the "Coal Sacks" of the southern hemisphere, the author finds less conspicuous examples in photographs of many parts of the heavens. The remainder of the volume consists of observations and comments on the Zodiacal Light, the Aurora, and variable stars. W. B.

2. *A Philosophical Essay on Probabilities;* by Pierre Simon, Marquis de LaPlace. Pp. iv, 196. Translated from the sixth French edition by Frederick Wilson Truscott, and Frederick Lincoln Emory, (New York, John Wiley & Sons, and London, Chapman & Hall, Limited.)—The rendering into English of La Place's classic in a form suitable for the class-room is the work of Professors Truscott and Emory. The translation is timely for two reasons. First, until recently, it could be truly said, on account of the excellence of the matter, that "not much has been added to our subject (probability) since the close of LaPlace's career." Secondly, within four or five years more has been added to the subject, both constructive and destructive, than during the interval of a hundred years. The application of the theory of probabilities to problems of evolution has resulted in new advances in the former to meet the demands of the latter. Among these results, especially significant is the monograph of Karl Pearson, "On the Mathematical Theory of Errors of Judgment, with Special References to the Personal Equation" (Phil. Trans., 1901, pp. 237–299), which apparently overturns the larger part of the current theory of errors of observation as expounded by Merriman and Airy. That such a revival of activity in this field is in progress is perhaps in a measure indicated by the reappearances of this earlier work. J. P. N.

Knowledge Diary and Scientific Hand-book for 1903. Pp. 112. London. 1902. Issued in conjunction with "Knowledge" (Knowledge Office, 326 High Holborn). The varied scope of this volume will be seen from the following statement of its contents. It contains original descriptive articles on the observation of comets and meteors; how to use an equatorial telescope; the microscope and its uses; aids to field botany; hints on meteorology; and monthly astronomical ephemeris. Also the paths of the principal planets for the year, illustrated with charts; astronomical notes and tables, with an account of the celestial phenomena of the year; and twelve star maps showing the night sky for every month in the year, with full descriptive account of the visible constellations and principal stars; a calendar of notable scientific events; an obituary for the year.

The publishers of *Knowledge* announce that in the future much more attention will be devoted to microscopy.



OUR FIELD

EMBRACES THE WHOLE WORLD OF LITERATURE

THE LIVING AGE

A MAGAZINE OF FOREIGN PERIODICAL LITERATURE

UNCHALLENGED QUALITY QUANTITY

PUBLISHED WEEKLY

BIOGRAPHY SCIENCE FICTION HISTORY POLITICS

THE WORLD'S GREATEST INTELLECTS

ARE REPRESENTED IN ITS PAGES

All of the writers whose portraits appear in the margin of this page were represented in last year's numbers of THE LIVING AGE; and with them **Katharine Tynan, Maxwell Gray, George Meredith, Fiona Macleod, Maurice Mæterlinck, Hilaire Belloc, Sir Rowland Blennerhassett, Eugene Melchior de Vogue, Paul Bourget, Henry Lawson, Arthur Christopher Benson, Max Beerbohm, Pierre de Coubertin, William Watson, Maxime Gorky, G. M. Trevelyan, Emily Lawless, Theophile Gautier, Prince Kropotkin,** and many others.

THE LIVING AGE

AS IT ENTERS UPON ITS

SIXTIETH YEAR AND 236TH QUARTERLY VOLUME

still maintains the high standard of literary excellence which has characterized it from the beginning. It presents in an inexpensive form, considering its great amount of matter, with freshness, owing to its weekly issue, and with a **satisfactory completeness** equalled by no other publication, the best **Essays, Reviews, Criticisms, Serial and Short Stories, Sketches of Travel and Discovery, Poetry, Scientific, Biographical, Historical and Political Information,** from the vast field of Foreign Periodical Literature.

ABSOLUTELY FREE

To all **NEW** Subscribers to **THE LIVING AGE** for the year 1903 there will be sent **FREE,** until the edition is exhausted, the **THIRTEEN WEEKLY ISSUES** for the three months, October, November and December, **making a large octavo volume of 824 pages.**

Send at Once and Secure Advantage of this Splendid Offer

Published every Saturday, and giving about **3,300 pages a year** of the **World's Best Literature,** popular, yet of permanent value.

Subscription Price, $6.00 a Year **Single Number, 15 Cents**

THE LIVING AGE COMPANY

P. O. Box 5206 13½ BROMFIELD STREET, BOSTON

Just out:

THE NEW PENFIELD COLLECTION OF CRYSTAL-MODELS

225 models to illustrate Chapter V of the

Brush-Penfield Determinative Mineralogy and Blowpipe Analysis.

"A feature of the collection is that with only a few exceptions the models represent prominent types or habits of common minerals. . . . The models, moreover, illustrate a very important feature of crystals, namely that the forms which are prominent and determine the crystal habit are, with few exceptions, those to which simple indices may be assigned.

"It is certain that those who are studying crystallography will find it a great advantage to have at hand not only models which correspond to a standard text, but, also, types which have been carefully selected as representatives of the important classes of crystals in the mineral kingdom."—SAMUEL L. PENFIELD.

NEW HAVEN, CONN., February 1, 1901.

Collection of 225 models (of pear-tree wood), . . . 230 Marks.

Now ready:

The new collection of 335 specimens and sections of rocks,

according to

H. Rosenbusch: Elemente der Gesteinslehre, 2d ed., 1901,

Accompanied by a text-book: "*Petrographisches Praktikum*," giving a short description of the petrographical microscope and how to use it, and also of the macroscopical and microscopical features of all the specimens of this collection;

Arranged by *Prof. Dr. K. Busz of Münster i.W.*

This collection is intended for the practical use of students and contains typical representatives of all important types of rocks, massive as well as sedimentary and crystalline schists. Aided by the text-book it will be found easy to become acquainted with the use of the microscope, with the features exhibited by rock-forming minerals and with determination of the latter.

Out of this collection two smaller ones have been arranged of 250 and 165 specimens respectively:

Collection I.	335 specimens of rocks, ...	380	Marks.
" I[a].	335 thin sections, ...	420	"
" II.	250 specimens of rocks, ...	270	"
" II[a].	250 thin sections, ...	310	"
" III.	165 specimens of rocks, ...	170	"
" III[a].	165 thin sections, ...	205	"

Collections of Minerals, Fossils, Meteorites purchased for cash or exchanged.

DR. F. KRANTZ,

RHENISH MINERAL OFFICE,

BONN-ON-RHINE, GERMANY.

ESTABLISHED 1833. ESTABLISHED 1833.

Dynamical and Structural Geology

A few of the more important and showy forms recently received in this department are:

ORBICULAR GRANITE.

Kortfors, Sweden. Of this interesting rock we have but three specimens on hand. The concretions are mainly hornblende imbedded in a coarse-grained light colored granite, making a strong contrast between the matrix and the concretions, the latter being from 2½ to 3 inches in diameter; polished slab 8 x 19 in. in diameter, $20.00; larger, $22.00 and $30.00.

Kangasniemi, Finland. In this rock the concretions are light colored surrounded by bands of hornblende, the compactness of the concretion forming a strong contrast to the coarse crystalline structure of the matrix. The concretions range from 4 to 6 inches in diameter. Specimens from $6.00 to $30.00.

Quonochontaug, Rhode Island. This is the only Orbicular Granite we have ever seen from America. The concretions are mainly hornblende with granite centers intermediate in color between the above two, and average from 1 to 2½ inches in diameter; polished slices from $6.00 to $13.00.

Orbicular Diorite (Napoleonite, Corsite). This well-known rock is now quite rare. The concretions, consisting of Anorthite, Hornblende and some Quartz, are comparatively uniform in size, averaging about 1½ inches in diameter; magnificently polished slabs of this rare rock from $4.00 to $15.00.

The above four rocks present a fine suite of concretionary structure as displayed in eruptive rocks; tracings of slices with size and position of concretions sent on application.

FAULTED SANDSTONE.

Hot Springs, S. D. We have a few specimens of this beautiful sandstone consisting of narrow layers ranging in color from light yellow to dark purple, showing in some instances from 3 to 10 distinct faults on same slab.

Slabs from $1.00 to $3.50.

TRAP DIKES IN GRANITE.

Norway, Maine. A fine suite of these either in polished slabs or the rough masses, some showing single dikes, others showing two dikes on same slab from a fraction of an inch to 2½ inches in diameter; 50c. to $15.00.

Three polished slices showing crossed dikes, with a fault at contact of the two dikes, $6.00 to $8.00.

METAMORPHISM.

Blue Pyroxene partially changed to Serpentine, from Gila River, N. M., the centers of these polished slabs being a light azure blue pyroxene with its edges changed to a translucent rich colored Serpentine, a beautiful combination of color. We have but a half-dozen slices of this rare rock on hand. $3.50 to $6.00.

PHENOMENAL SERIES OF ROCKS.

We have just compiled a collection consisting of 83 specimens illustrating Dynamical and Structural Geology, specimens averaging 3 x 4 inches. Price, $45.00.

This collection is accompanied by a descriptive catalogue describing the various phenomena as represented in the collection.

Circulars on application.

WARD'S NATURAL SCIENCE ESTABLISHMENT

76-104 COLLEGE AVE., ROCHESTER, N. Y.

BAKER & CO.
METALLURGISTS IN PLATINUM

410 N. J. R. R. AVE., NEWARK, N. J.

Beg to announce that they are the sole Licensees for the manufacture of the Shimer Crucible.

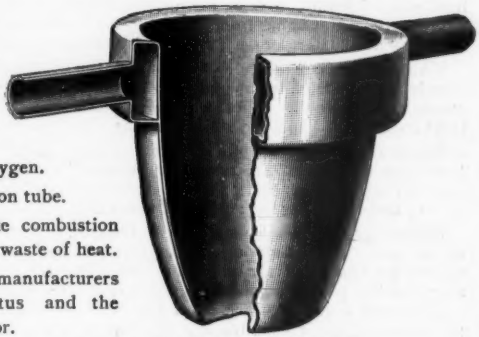
Having the following advantages:

It uses air instead of oxygen.

It requires no combustion tube.

It secures the complete combustion of graphite. There is no waste of heat.

We are also the sole manufacturers of the Tucker Apparatus and the Howard Density Regulator.



SHIMER CRUCIBLE

Our "Data Concerning Platinum, Etc.," and our brochures on the above specialties, should be in every chemist's library. They are free on request.

N. Y. OFFICE, 120 LIBERTY STREET

THE AMERICAN NATURALIST

A Monthly Journal Devoted to the Natural Sciences in Their Widest Sense.

Since the foundation in 1867 by four of the pupils of Louis Agassiz, THE AMERICAN NATURALIST has been a representative American magazine of Natural History and has played an important part in the advancement of science in this country.

The journal aims to present to its readers the leading facts and discoveries in the fields of Anthropology, General Biology, Zoology, Botany, Paleontology, Geology and Mineralogy, and the various sub-divisions of those subjects.

Annual Subscription, $4.00 net, in advance. Single Copies, 35 Cents.
Foreign Subscription, $4.60.

GINN & COMPANY, Publishers.

29 BEACON STREET, BOSTON, MASS.

6 t., Feb. '03—alt.